Prime Item Development Specification: Fluids Integrated Rack

Fluids and Combustion Facility Fluids Integrated Rack

Final
October 20, 2000

AUTHORIZED by CM when under FORMAL Configuration Control	
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Prime Item Development Specification
for the
Fluids and Combustion Facility
Fluids Integrated Rack

Configuration Item No.: 67213MFAF15000
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PREFACE

The National Aeronautics and Space Administration is developing a modular, multi-user experimentation facility for conducting fluid science and combustion science experiments in the microgravity environment of the International Space Station (ISS). This facility, called the Fluids and Combustion Facility (FCF), consists of three test platforms: the Fluids Integrated Rack (FIR), the Combustion Integrated Rack (CIR), and the Shared Accommodations Rack (SAR). This document defines the requirements for the FIR and is the source for FIR technical and verification requirements.

This specification was prepared as a Type B1 Prime Item Development Specification, Form 1b, as defined in NASA document SSP 41171. It defines the FIR development item, applicable documents, characteristics that the FIR must exhibit, design and construction requirements, computer resource requirements, logistics requirements, personnel and training requirements, and characteristics of any subordinate elements. This document also discusses quality assurance provisions, preparation for shipping, and notes.

**PRIME ITEM DEVELOPMENT SPECIFICATION:
FLUIDS AND COMBUSTION FACILITY
FLUIDS INTEGRATED RACK (FIR)**

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REVISION PAGE
FIR PRIME ITEM DEVELOPMENT SPECIFICATION

Revision	Date	Description of Change or ECO's Incorporated	Verification and Date
Final	10/20/00	Baseline	10/25/00

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1 SCOPE

This specification establishes the performance, design, development, and qualification requirements for the Fluids Integrated Rack (FIR) in both its launch configuration and its on-orbit configuration. The FIR is part of the United States Laboratory Module (US Lab) Fluids and Combustion Facility (FCF) of the International Space Station (ISS). This specification is prepared per the format as specified in SSP 41171. The FIR for the Ground Integration Unit, Engineering Development Unit and the Payload Training Center Unit are covered in the Ground Segment Specification, FCF-SPEC-0005.

1.1 Identification.

This specification covers the FIR configuration items 67213MFAF15000.

1.2 Classification.

No type, grade, class, or other similar designation is applicable at this time.

1.3 International standardization agreement code.

International standardization agreement code numbers are not applicable to the configuration item defined by this specification.

1.4 Assembly overview.

The FIR is part of a modular, multi-user facility whose primary purpose is to perform sustained, systematic research in the discipline of fluid physics science. The FIR is the second FCF segment to be installed as a permanent facility within the US Lab.

1.5 Exceptions.

Approved exceptions to the requirements of this specification are provided in APPENDIX G.

1.6 Open issues, open items or TBDs

Any open issues, open items or TBDs in this document are denoted by <TBD>. TBDs are given in APPENDIX H.

2 APPLICABLE DOCUMENTS

This section discusses all documents, including both government and nongovernment documents, applicable to this specification.

2.1 Government documents.

The following paragraphs list all the government documents referred to in this document.

2.1.1 Specifications, standards, and handbooks.

The following specifications, standards, and handbooks of the exact issue shown form a part of this specification to the extent specified herein. In the event of a conflict between documents referenced herein and the content of this specification, the content of this specification shall be considered a superseding requirement.

2.1.1.1 Federal specifications.

Not applicable.

2.1.1.2 Military specifications.

MIL-C-38999 Rev. J, 04/06/90	Connector, Electrical, Circular, Miniature, High Density Quick Disconnect, (Bayonet, Theaded, and Breech Coupling), Environmental Resisting, Removable Crimp and Hermitic Solder Contacts, General Specification for
MIL-C-5015 Rev. G(5) SUP 03/15/94	Connectors, Electrical, Circular Theaded, An Type, General Specification for
MIL-C-81569 Rev. B Amd. 2 10/01/90	Connectors, Electrical Rectangular, Crimp Contact, General Specification for
MIL-C-83733 Rev. C Amd. 1 10/30/89	Connectors, Electrical Miniature, Rectangular Type, Rack to Panel, Environmental Resisting, 200° F Total Continuous Operating Temperature, General Specification for

2.1.1.3 Federal standards.

FED-STD-595 Rev. B 12/15/89	Federal Standard Colors Used in Government Procurement

2.1.1.4 Federal information processing standards.

Not applicable.

2.1.1.5 Military standards.

MIL-STD-461	Electromagnetic Emissions and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-1686 Rev. C 10/25/95	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) Document
MIL-STD-1553B	Digital Time Division Command/Response Multiplex Data Bus Handbook

2.1.1.6 Military handbooks.

MIL-HDBK-1553	Digital Time Division Command/Response Multiplex Data Bus Handbook

(Copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents order desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.1.2 Other government documents, drawings, and publications.

The following other government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the exact issue shown applies to this specification.

2.1.2.1 Other government documents.

FCF-PLN-0036 Rev. A 02/00	Fluids and Combustion Facility Material and Processes Control Plan
FCF-DOC-002 Rev. A 04/99	Science Requirements Envelope Document – Fluids and Combustion Facility
FCF-DOC-004 Rev. A 04/99	Compliance Matrix, Science Requirements Envelope Document – Fluids and Combustion Facility
FCF-SPC-0001	Systems Specification – International Space Station Fluids and Combustion Facility
JSC 27199 Rev. A 03/97	End Item Specification for the International Space Station Portable Utility Light
FIR-PLN-0147	Fluids Integrated Rack Verification Plan
JSC 27260 Rev. B 09/08/97	Decal Process Document and Catalog
JSC, MA2-95-048	NASA IVA Touch Temperature Safety interpretation letter
MSFC-STD-275 Rev. A 05/22/64	Marking of Electrical Ground Support Equipment, Front Panels, and Rack Title Plates

MSFC-SPEC-250 Rev. A 10/01/77	Protective Finishes for Space Vehicle Structures and Associated Flight Equipment, General Specification for Document
MSFC-STD-531	High Voltage Design Criteria
NASA-STD-5003	Fracture Control Requirements for Payloads Using the Space shuttle
NHB 5300.4(1B) 04/69	Quality Program Provisions for Aeronautical and Space System Contractors
NHB 6000.1	Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components
NSTS 1700.7 ISS Addendum	Safety Policy and Requirements for Payloads Using the International Space Station
NSTS 13830	Implementation Procedure for NSTS Payloads System Safety Requirements
NSTS 18798	Interpretations of National Space Transportation System (NSTS) Payload Safety Requirements
SN-C-0005	NSTS Contamination Control Requirements Manual
SSP 30237	Space Station Requirements for Electromagnetic Emissions and Susceptibility Requirements
SSP 30238	Space Station Electromagnetic Techniques
SSP 30240	Space Station Grounding Requirements
SSP 30242	Space Station Cable/Wire Design and Control Requirements for Electromagnetic Compatibility
SSP 30243	Space Station Requirements for Electromagnetic Compatibility
SSP 30245	Space Station Electrical Bonding Requirements
SSP 30257:004	Space Station Program Intravehicular Activity (IVA) Restraints and Mobile Aid Standard Interface Control Document (ICD)
SSP 30262:013	Smoke Detector Assembly Standard ICD
SSP 30312	Electrical, Electronic, and Electromechanical Parts Management and Implementation Plan for Space Station Program
SSP 30423 Rev. F 03/95	Space Station Approved Electrical, Electronic, and Electromechanical Parts List
SSP 30426	External Contamination Control Requirements
SSP 30482 (V1)	Electric Power Specifications and Standards, Vol. 1: EPS Performance Specifications
SSP 30482 (V2)	Electric Power Specifications and Standards, Vol. 2: Consumer Restraints
SSP 30512	Ionizing Radiation Design Environment
SSP 30573	Space Station Program Fluid Procurement and Use Control Specification
SSP 41171	Preparation of Program-Unique Specifications – International Space Station Program

SSP 41002	International Standard Payload Rack to NASA/NASDA Modules Interface Control Document
SSP 41017	Rack to Mini Pressurized Logistics Module ICD Part 1 and Part 2
SSP 41175-02	Software ICD Part 1 Station Management and Control to ISS Book 2 General Interface Software Interfaces Requirement
SSP 50005	International Space Station Flight Crew Integration Standard (NASA-STD-3000/T) Document
SSP 50184	High Rate Data Link Physical Media, Physical Signaling and Protocol Specifications
SSP 50313	Display and Graphical Commonality Standard
SSP 52005	ISS Payload Flight Equipment and Guidelines for Safety Critical Structures
SSP 52050	Software Interface Control Document Part 1, International Standard Payload Rack to International Space Station
SSP 57000	Pressurized Payloads Interface Requirements Document
SSP 57001	Pressurized Payload Hardware ICD
SSP 57002	Pressurized Payload Software ICD
SSP 57007	ISPR Structural Integrator's Handbook
SSP 57010	Pressurized Payloads Generic Payload Verification Plan
SSP 57011	Payload Verification Plan
SSP 57020	Pressurized Payload Accommodations Handbook
SSP 57218	FCF FIR Hardware Interface Control Document (ICD)
SSQ 21635	Connectors and Accessories, Electrical, Rectangular, Rack and Panel
SSQ 21654	Cable, Single Fiber, Multitude, Space Quality, General Specification for Document
SSQ 21655	Cable, Electrical, MIL-STD-1553B Data Bus, Space Quality, General Specification for Document

2.1.2.2 Drawings.

Not applicable.

2.1.2.3 Publications.

Not applicable.

2.2 Nongovernment documents.

The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of a conflict between the documents referenced herein and the content of this specification, the content of this specification shall be considered a superseding requirement.

2.2.1 Specifications.

2.2.2 Standards.

ISO/IEC 8802-3	Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specification

2.2.3 Other publications.

220G07455	Rack Handling Adapters – Upper Structure
220G07470	Rack Handling Adapters – Lower Structure
220G07475	Rack Handling Adapters - KSC Lower Structure
220G07500	Rack Shipping Containers
CCSDS 301.1-B-2	CCSDS Time Code Format
CCSDS 701.0-B-2	Advanced Orbiting Systems, Network and Data Links: Architectural Specification, Blue Book
EIA/TIA RS-250-C	Electrical Performance for Television Relay Facility
D683-10007	Fire Detection Assembly
683-17103	Fluid System Server Interface Definition Drawing
NTC-7	Video Facility Testing Technical Performance Objectives (NTC)
D684-10056-01	International Space Station, Prime Contractor Software Standards and Procedures Specification

2.3 Order of precedence for document.

In the event of a conflict between this document and other documents referenced herein, the requirements of this document shall apply. In the event of a conflict between this document and the contract, the contractual requirements shall take precedence over this document. All documents used, applicable or referenced, are to be the issues defined in the Configuration Management (CM) contract baseline. All document changes, issued after baseline establishment, shall be reviewed for impact on scope of work. If a change to an applicable document is determined to be effective, and contractually approved for implementation, the revision status will be updated in the CM contract baseline. The contract revision status of all applicable documents is available by accessing the CM database. Nothing in this document supersedes applicable laws and regulations unless a specific exemption has been obtained.

3 REQUIREMENTS

The requirements that form this document are delegated from FCF-DOC-002, in association with FCF-DOC-004, FCF-SPC-0001, and SSP 57000 as listed in the Dynamic Object Oriented Requirements System (DOORs) program.

3.1 FIR definition.

3.1.1 FIR description.

The FIR can either be in a launch configuration or an on-orbit configuration. It is packaged in a program furnished International Standard Payload Rack (ISPR). The FIR in the launch configuration is placed in a Multi-Purpose Logistics Module (MPLM) along with associated stowage items that will make up the FIR on-orbit configuration. Once the FIR is installed in the US Lab, astronauts will complete the assembly to the FIR on-orbit configuration. Figure 1 and Figure 2 show the launch and on-orbit FIR configurations. In conjunction with Principal Investigator (PI) hardware and software, the FIR will perform sustained, systematic research in fluid physics science. Most of the requirements derived from FCF-DOC-002 cannot be met or verified without PI or PI-simulated hardware and/or software.

3.1.2 FIR mission.

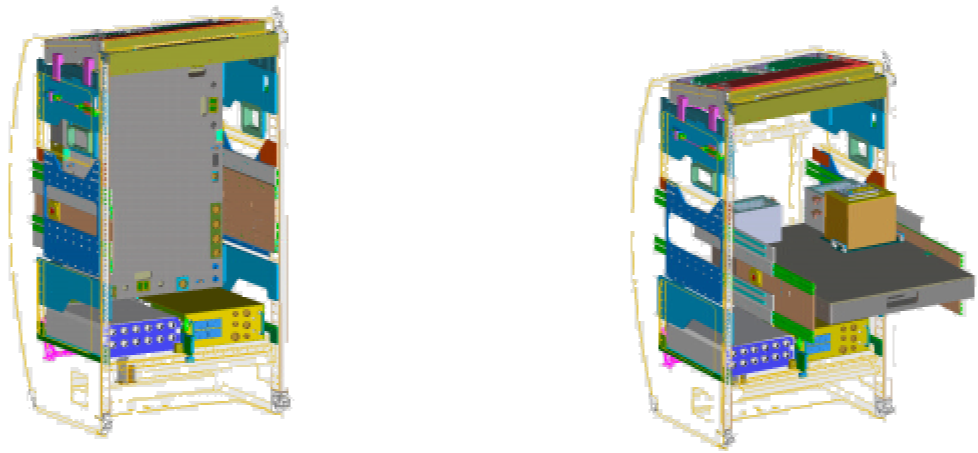
The FIR mission is to perform microgravity experiments in fluid physics science over the life of the FCF.

3.1.3 Threat environment.

Not applicable.

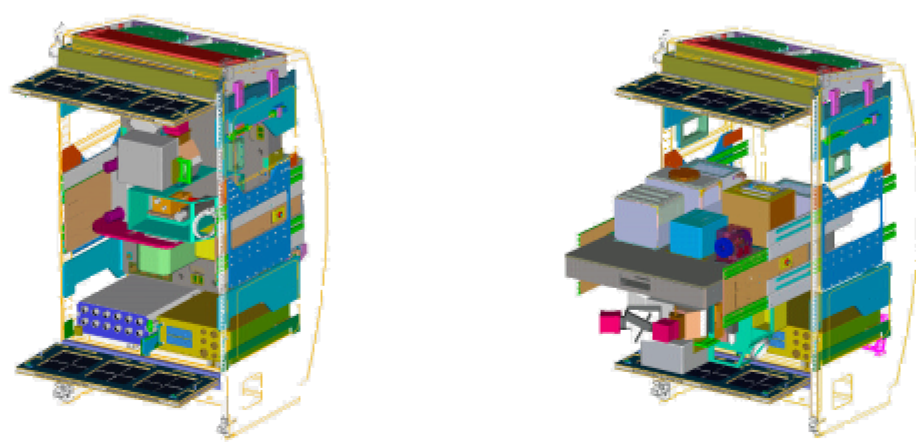
3.1.4 FIR functional schematic.

The FIR is nonoperational in its launch configuration. Figure 3 shows the functions of the FIR. The FIR will be designed to allow investigation in fluid physics science to better understand the fluid physics processes that occur on Earth. The microgravity environment allows for measurement and observation of fluid physics phenomena and processes that cannot be made in sustained gravity. The modular design of the FIR assemblies allows for flexibility in configuring for specific experiments and easy maintainability of the hardware.



Optic bench front view   Optic bench rear view

Figure 1. FIR launch configuration



Optic bench front view   Optic bench rear view

Figure 2. FIR on-orbit configuration

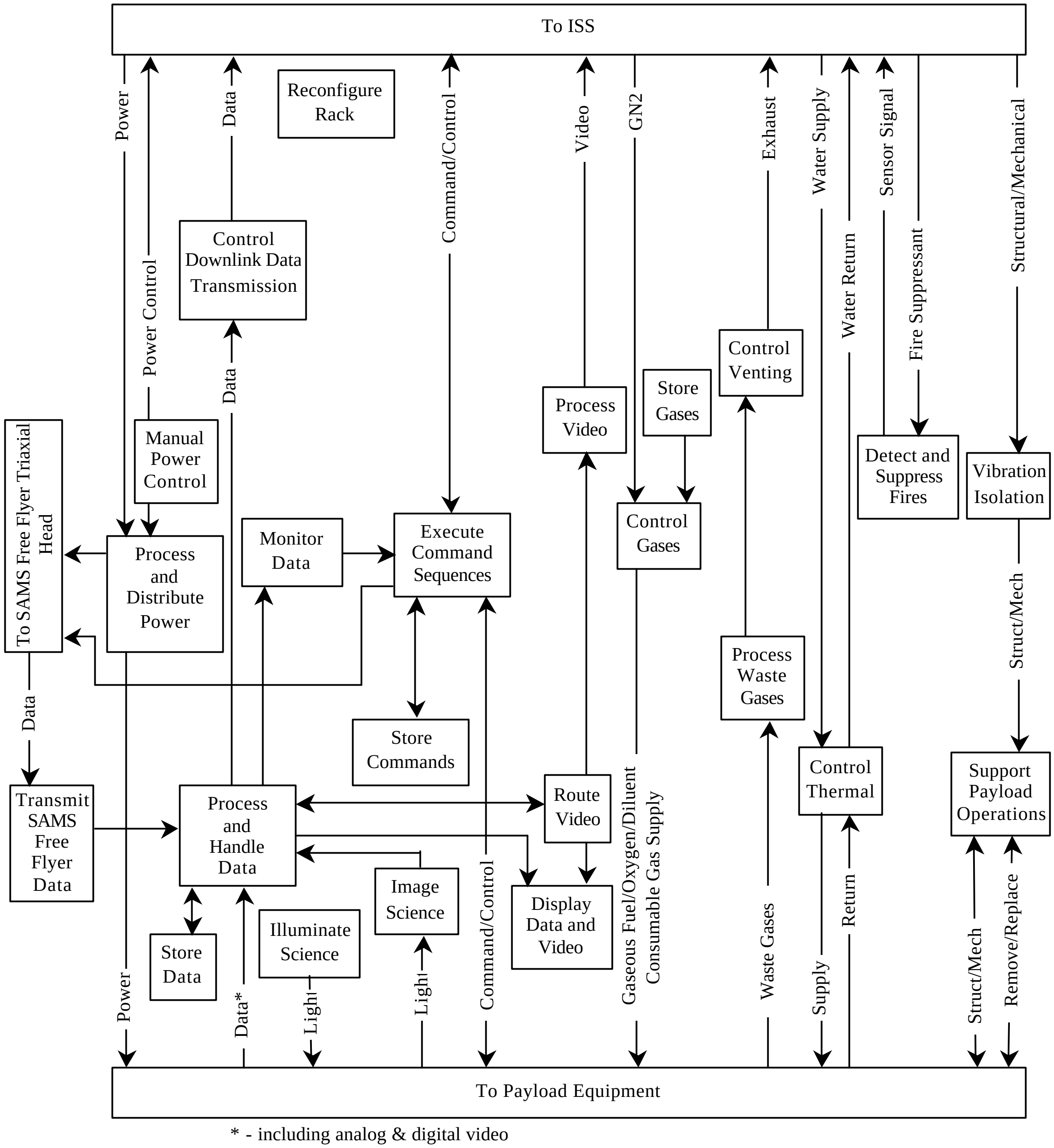


Figure 3. FIR functional schematic

3.1.5 Interfaces.

3.1.5.1 External interfaces.

The external interfaces for the FIR in the launch configuration are the physical attachments of the FIR to the MPLM and are defined in SSP 41017. All assemblies not mounted in the rack will be in stowage containers.

Figure 4 shows the external and experiment interfaces of the FIR to the US Lab. SSP 57007 gives the physical interfaces for the FIR to the US Lab and MPLM. Table I lists the electrical/data interfaces to the US Lab. Table II gives the fluids interfaces connecting the FIR to the US Lab.

Table I. Electrical/data interfaces between FIR and US Lab

Interface	Module Connector	Part Number
Main Power	J1	NATC07T25LN3SN
Essential/Auxiliary Power	J1	NATC07T25LN3SA
1553 Bus A	J3	NATC07T15N35SN
1553 Bus B	J4	NATC07T15N35SA
HRDL	J7	NATC07T13N4SN
Optical Video	J16	NATC07T15N97SB
Fire Detection System/Power Maintenance	J43	NATC07T13N35SA
LAN-1	J46	NATC07T11N35SB
LAN-2	J47	NATC07T11N35SB

Table II. Fluids interfaces used to connect the FIR to the US Lab

Interface	Part Number
Thermal Control System (TCS) Moderate Supply	683-16348, male, Category 6, Keying B
TCS Moderate Return	683-16348, male, Category 6, Keying C
Gaseous Nitrogen	683-16348, male, Category 8, Keying B
Vacuum Exhaust	683-16348, male, Category 3, Keying B
Vacuum Resource	683-16348, male, Category 3, Keying A

In the event the FIR must be installed into the Columbus Orbital Facility (COF), the FIR will be operated in a degraded condition and will use the interfaces as specified in SSP 57000 for the COF.

3.1.5.2 Internal interfaces.

The internal physical interfaces, PI-specific hardware, and assemblies within the FIR are given in APPENDIX C. The specific interface descriptions are specified in the respective product specifications. APPENDIX D shows the electrical/data interfaces for PI-specific hardware and assemblies within the FIR Appendix F lists the internal environmental control system interfaces.

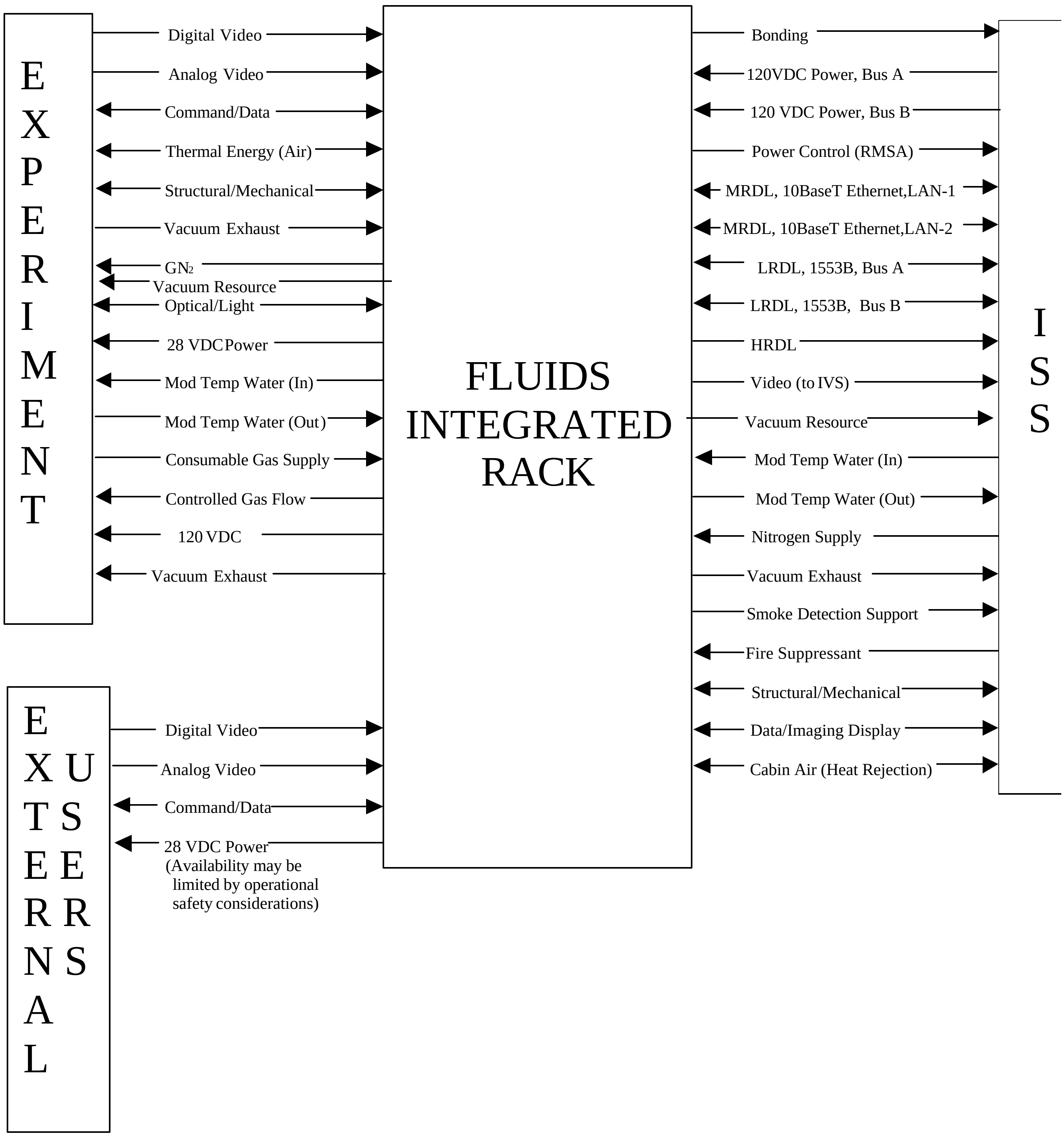


Figure 4. FIR external interface and experiment interface schematic

3.1.6 Major components list.

The below list includes the nongovernment furnished major components that describe the FIR:

1. High Resolution Camera Assembly -67213MFAF70200
2. Color Camera Assembly -67213MFAF70250
3. Ultra-High Frame Rate Camera Assembly -67213MFAF70350
4. White Light Assembly -67213MFAF70700
5. Nd: YAG Laser Assembly -67213MFAF70900
6. Laser Diodes Assembly- 67213MFAF71000
7. Fluids Science Avionics Package Assembly -67213MFAF40000
8. PI Fluids Science Avionics Package Assembly -67213MFAF45000
9. High Resolution Image Acquisition Assembly -67213MFAF70010
10. Color Image Acquisition Assembly -67213MFAF70300
11. High Magnification Lens Assembly -67213MFAF70500
12. Macroscopic Lens Assembly #1 -67213MFAF70400
13. Macroscopic Lens Assembly #2 -67213MFAF70450
14. Macroscopic Lens Assembly #3 -67213MFAF70475
15. Collimator Assembly -67213MFAF70550
16. Scanning Mirror Assembly- 67213MFAF70600
17. Translational Stage Assembly -67213MFAF70050
18. Spot Cooling Fan Post Assembly-67213MFAF72000
19. Mobile Camera Mounting Post Assembly-67213MFAF72200
20. Optics Bench Assembly-67213MFAF20000
21. Rack Attachment Plates-67213MFAF20450
22. Optics Bench Assembly Rack & ATCS Seals-67213MFAF20400
23. Rack Center Post-67213MFAF20400
24. ESC Modifications (Air Diffuser & Outlet Duct) -67213MFAF80200
26. Input/Output Package (IOP) – 67211MFAB10000
27. Diagnostics Control Module (DCM) – 67211MFAB20000
28. Image Processing and Storage Unit (IPSU) – 67211MFAB30000
29. Rack Door Closure – 67211MFAG10000
30. Optics Bench Slides-67211MFAG20000
31. IOP Rack Attachments-67211MFAG30000
32. EPCU Rack Attachments-67211MFAG40000
33. ATCU Rack Attachments-67211MFAG50000
25. Optics Bench Pins-67211MFAG60000
26. Removable Handle Assembly-67211MFAG70000
27. Electrical Power Control Unit (EPCU) Structure – 67211MFLG300
28. Air Thermal Control Unit (ATCU) – 67211MFAD10000
29. Water Thermal Control System (WTCS) – 67211MFAD20000
30. Gas Interface System – 67211MFAD30000
31. Fire Detection and Suppression Assembly – 67211MFAD40000
32. EPCU Shutoff Switch Assembly- <TBD 03-04>
33. Atmosphere Monitoring Assembly- <TBD 03-05>

3.1.7 Government furnished property list.

The below list gives the government furnished major components of the FIR:

1. Electrical Power Control Unit (EPCU) – EP4001-9
2. Spacecraft Acceleration Measurement System (SAMS) Free Flyer – 60005MA12100
3. Rack Maintenance Switch Assembly (RMSA)- 67212MFLB3

3.1.8 Government loaned property list.

Not applicable.

3.1.9 Program furnished property list.

The below list gives the program furnished major components of the FIR:

1. International Standard Payload Rack (ISPR) – 683-50243
2. Active Rack Isolation System (ARIS) – 683-61600

3.2 Characteristics.

3.2.1 Performance characteristics.

The FIR shall meet the performance characteristics requirements as specified herein from the requirements in FCF-DOC-002 and FCF-SPC-0001 allocated as specified in FCF-DOC-004 Chapter 2.

3.2.1.1 Utilization.

The FIR, with applicable PI hardware and resources, shall be designed to support 10 fluid physics experiments per year.

3.2.1.1.1 Minimum utilization.

The FIR, with applicable PI hardware and resources, shall be designed to support a minimum utilization of five fluid physics basis experiments as specified in FCF-DOC-002.

3.2.1.1.2 Additional utilization.

The FIR, with applicable hardware and resources, shall be capable of accommodating a minimum of five additional fluid physics experiments from commercial and/or international sources.

3.2.1.1.3 Utilization capacity.

The FIR, with applicable PI hardware and resources, shall be designed to meet a minimum of 80% of the proposed fluid physics experiments based on using the fluid physics basis experiments as specified in FCF-DOC-002 for the FIR design.

3.2.1.1.3.1 Basis experiment capacity.

The FIR, with applicable PI hardware and resources, shall be designed to meet a minimum of 80% of the fluid physics basis experiments' current/historical Science Requirements Document (SRD) test matrices using the fluid physics basis experiments as specified in FCF-DOC-002.

3.2.1.1.3.2 Initial scheduled experiment capacity.

<TBD 03-03>

3.2.1.2 FIR fluid physics science volume.

a. FIR shall provide a work volume dedicated to Fluid Physics experimentation. A majority of this volume shall nominally be set aside for PI experiment payload equipment that may be unique to a specific experiment.
b. The volume set aside shall be adequate to allow set-up and operation of at least 80% of the Fluid Physics basis experiments.

3.2.1.3 Accommodate experiment test cells.

The FIR shall be capable of accommodating fluid physics PI experiment payload test cells and containers in the range of sizes and capabilities required by the basis experiments.

3.2.1.4 Acceleration and vibration requirement.

3.2.1.4.1 Provide microgravity environment.

FIR shall be capable of providing a microgravity environment (at the test sample) that accommodates the envelope of limiting accelerations identified for the fluid physics basis experiments. Operational protocols may be used to support compliance with this requirement (e.g., scheduling to avoid major disturbances). Figure 5 illustrates the approximate upper limits on quasi-steady acceleration for each basis experiment. Figure 6 <TBD 03-01> illustrates the excluded zone for g-jitter. Figure 5 and Figure 6 are graphical statements of the requirements to be enveloped.

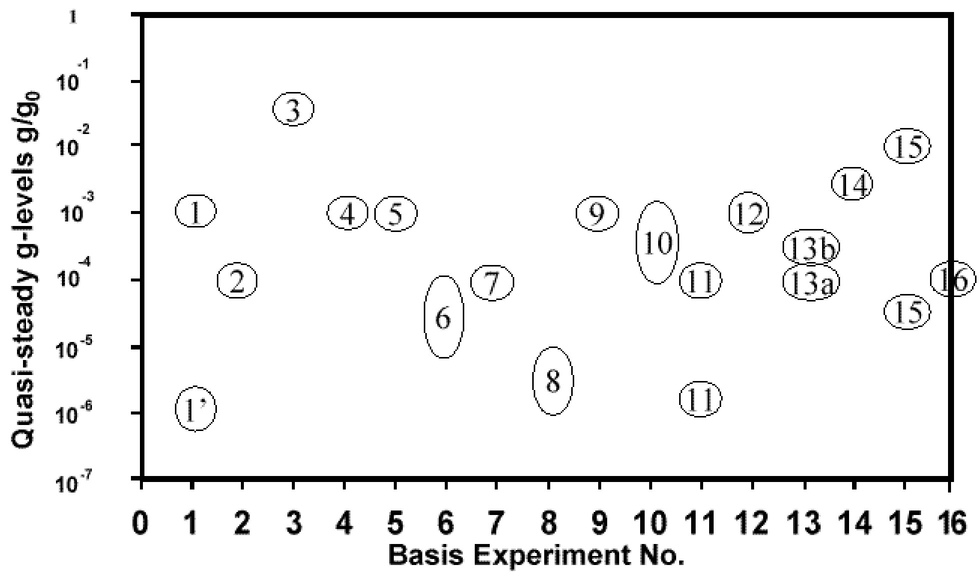


Figure 5. Maximum Quasi-steady g-Level Limits

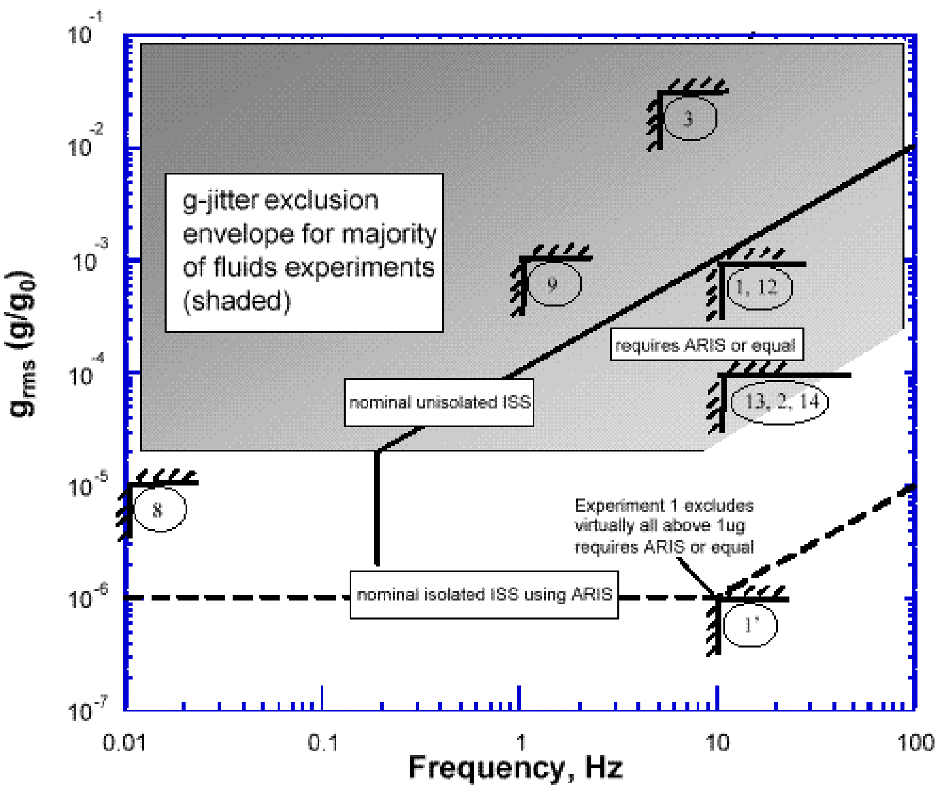


Figure 6. g-Jitter Exclusion Envelope for Fluids Experiments

3.2.1.4.2 Accommodate acceleration measurement device.

a. FIR shall accommodate an acceleration measurement device as close as practical to the test cell.
b. The acceleration measurement device shall be capable of measurements in three simultaneous orthogonal directions at levels from 10^{-2} to 10^{-6} g/g_0 and frequencies from 0.01 to 300 Hz. See Appendix G.10 for exception to this requirement.
c. Accuracy of the acceleration measurement device shall be within 10 percent of selected full-scale acceleration range.
d. The data shall be available in near real time and post mission.

3.2.1.5 Provide stable work volume temperature.

FIR shall provide stable temperatures within the fluid physics work volume in the range of 20 to 30 °C during periods of operation.

3.2.1.6 Maintain test cell temperature.

FIR shall support the ability of PI experiment payload to maintain required test cell (and other) temperatures inside the PI hardware over a minimum range of -20 to 100 °C. See Appendix G.5 for exception to this requirement.

3.2.1.7 Control air circulation.

a. FIR shall provide the capability to control air circulation within and around measurement systems that are susceptible to disturbance caused by uncontrolled air circulation.

b. At times the air must be still and at times it must be circulated to obtain relatively uniform conditions.

3.2.1.8 Contain optical elements.

a. FIR shall provide physical and procedural controls to limit levels of contamination on the optical elements of optical systems during handling, setup, operation, and storage.

b. Optical element transmission shall remain greater than 60 percent of the day 1 value (previously verified).

c. Replacement of contaminated elements can be used as one aspect of control.

3.2.1.9 Background lighting.

FIR, with applicable PI hardware, shall provide uniform, broad band lighting (nominally white light) at the payload equipment test cell.

3.2.1.9.1 Background lighting intensity.

a. Intensity and uniformity shall be consistent with image resolution requirements.
b. The absolute mean intensity shall be variable over a wide range.
c. The mean intensity shall be determinable with an accuracy of approximately 1 percent before, during, and after an experiment test point run.
d. The mean intensity shall be stable within approximately 1 percent during a test point run. See Appendix G.8 for exception to this requirement.

3.2.1.9.2 Background lighting field of view.

a. The dimensions of the illuminated area shall be capable of adjustment over a range of sizes as required by the basis experiments. See Appendix G.8 for exception to this requirement.
b. The nominal size shall be an approximately 10 cm x 10 cm illuminated field of view.

3.2.1.10 Laser light illumination.

a. FIR shall provide laser sources, optical systems, power, and control to enable laser illumination over the range of wavelength, polarization, power, and other characteristics required by the majority of fluid physics basis experiments.
b. FIR shall provide collimated beams and light sheets having adjustable size and position. See Appendix G.11 for exception to this requirement.
c. Laser light sources used for background lighting shall be subject to the same intensity uniformity standards as the broad band background lighting sources (see 3.2.1.9).

3.2.1.11 Provide interface to ISS vacuum vent.

FIR shall provide PI experiment payload access to the International Space Station (ISS) Vacuum Vent System.(VVS) and Vacuum Resource System (VRS).

3.2.1.12 Provide on-orbit stowage.

FIR shall provide on-orbit stowage volume having power and cooling to accommodate such needs as thermal control, stirring, and tumbling of experiment samples whenever required.

3.2.1.13 Accommodate fluids test point quantity and duration.

FIR shall accommodate the range of quantity of test points and test point durations of the fluid physics basis experiments per the estimates in Figure 7. Figure 7 is a graphical statement of the requirements. See Appendix G.6 for exception to this requirement.

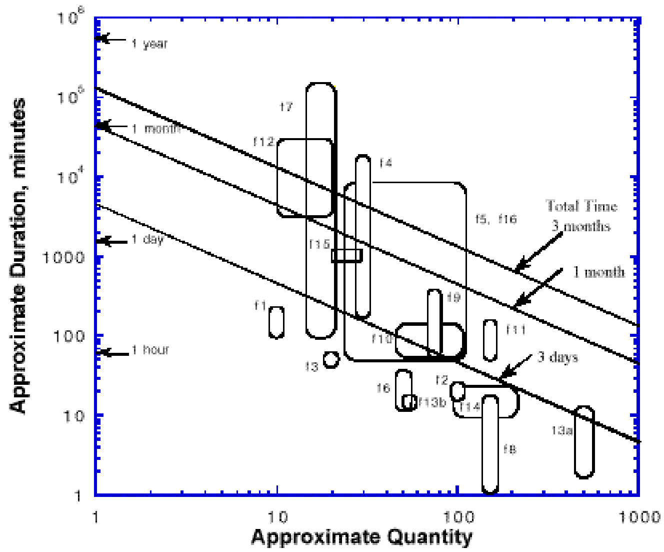


Figure 7. Quantity of Test Points and Their Duration

3.2.1.14 Basis experiment imaging equipment.

a. FIR shall provide a set of imaging capabilities (e.g., subassemblies incorporating cameras, lenses, mirrors, et al) covering, nominally, the entire visible light spectrum.
b. Imaging capabilities shall be the types and quantities required by the basis experiments.

3.2.1.14.1 PI-provided imaging equipment

a. FIR shall accommodate PI-provided cameras and supporting hardware which are compatible with power, data acquisition, and work volume capabilities.
b. FIR, with applicable PI hardware, shall provide imaging at wavelengths 14 µm to 390 nm.

3.2.1.14.2 Provide IR camera.

The FIR shall provide one, remotely controllable infrared (IR) camera with a wavelength range of 8 to 14 microns. See Appendix G.16 for exception to this requirement.

3.2.1.15 Simultaneous imaging

FIR, with applicable PI hardware, shall accommodate simultaneous imaging of the test cell from at least two orthogonal directions as required by the basis experiments.

3.2.1.16 Downlink images

a. FIR shall provide downlink for at least two imaging channels in near real time with frame rate and resolution adequate to monitor the progress of the test point.
b. FIR shall provide downlink for at least two imaging channels in near real time with frame rate and resolution adequate for image analysis.

c. FIR shall provide downlink for at least two imaging channels in near real time with frame rate and resolution adequate for interactive control of the basis experiments.

3.2.1.17 Position fluids element imaging equipment.

a. FIR shall provide positioners, optical systems, power control, and procedures to reproducibly position and align light sources, optics, and other experimental components located within the dedicated fluid physics volume.
b. The relative positions of components shall be reproducible and knowable with the accuracy and precision required by the majority of basis experiments.

3.2.1.18 PI imaging equipment positioning

The FIR, with applicable PI hardware (and/or software) shall support the position and alignment adjustment of PI-provided optical components with a precision of approximately a micron or less relative to other optical components, as required for practical implementation of the basis experiments.

3.2.1.19 Provide field of view

FIR imaging shall accommodate the ranges of field of view necessary to support the basis experiments per the estimates in Figure 8. Figure 8 is a graphical statement of the requirements to be enveloped.

3.2.1.20 Provide resolution.

FCF imaging shall accommodate the ranges of resolution necessary to support the basis experiments per the estimates in Figure 8. Figure 8 is a graphical statement of the requirements to be enveloped.

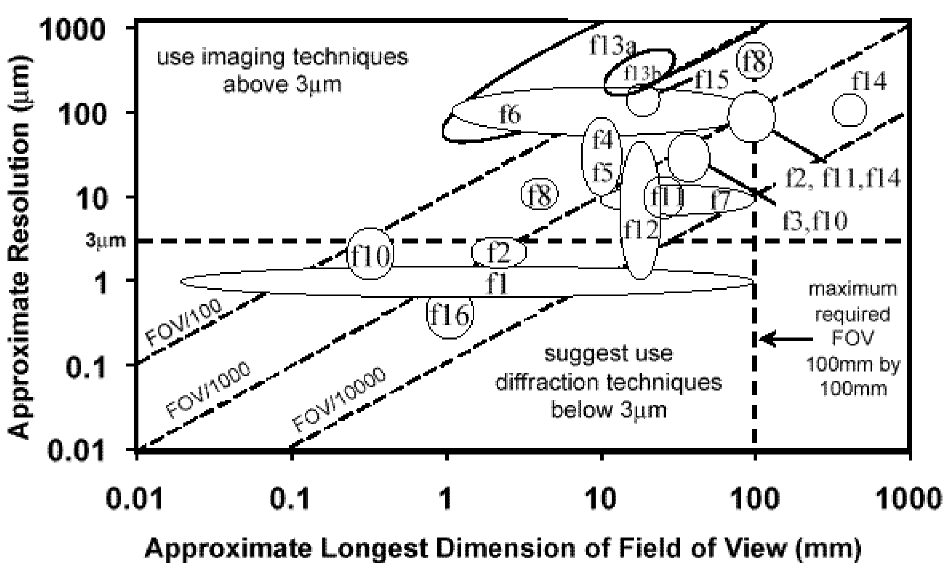


Figure 8. Field of View versus Resolution

3.2.1.21 Particle speed vs. field of views.

FIR shall accommodate the range of fields of view (FOV) and expected particle velocities required by the basis experiments per the estimates in Figure 9. Figure 9 is a graphical statement of the requirements to be enveloped. See Appendix G.7 for exception to this requirement.

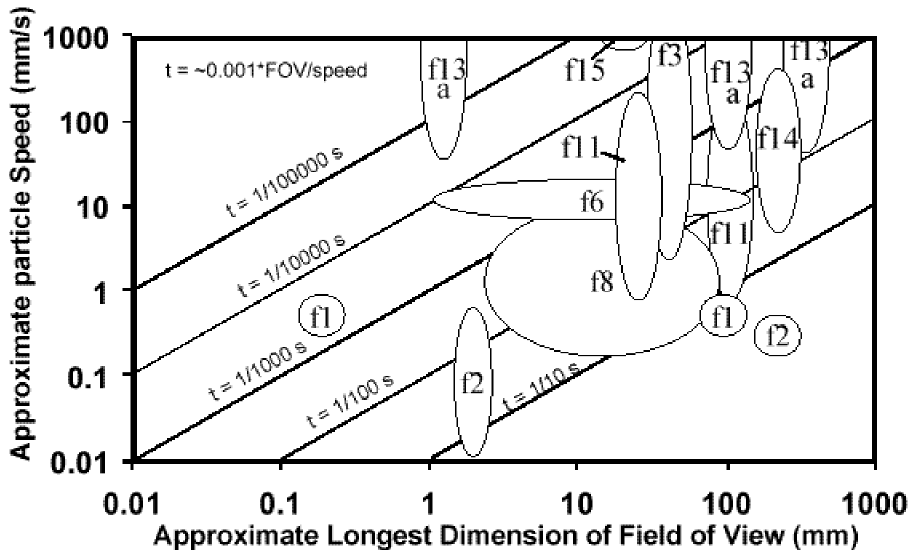


Figure 9. Exposure Duration (t) as a Function of Particle Speed

3.2.1.22 Framing rate and recording duration.

The combination of Camera Packages shall collectively provide the range of framing rate and range of quantities of images required by the basis experiments per Figure 10. Figure 10 is a graphical statement of the requirements to be enveloped.

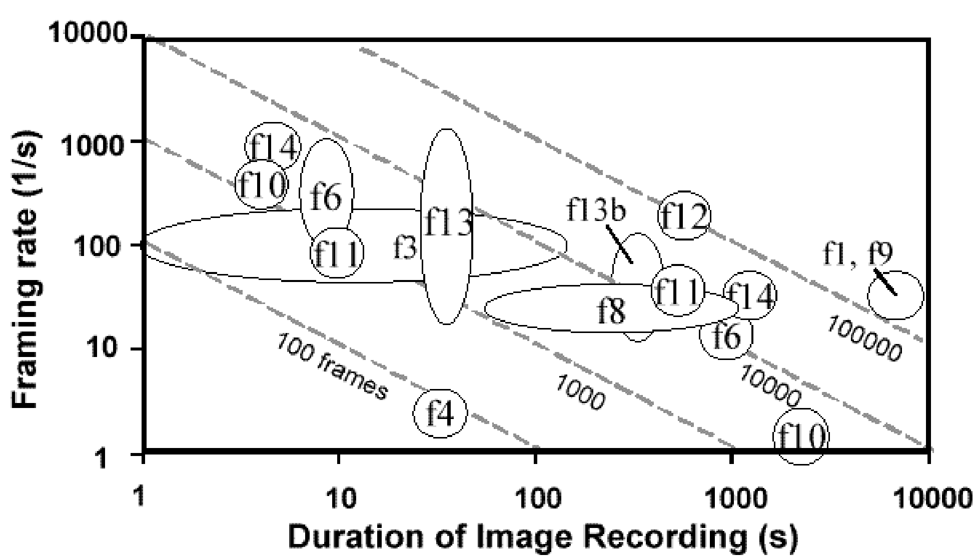


Figure 10. Recording Duration for Various Framing Rates

3.2.1.23 Removable storage media.

This is an FCF system level requirement and is addressed in the *SAR Prime Item Development Specification* (FCF-SPC-0004).

3.2.1.24 Diagnostics

FIR shall provide diagnostics commonly needed by fluid physics experiments.

3.2.1.25 Temperature measurements.

FCF shall be capable of accommodating acquisition and storage of temperature data from a variety of transducers at various ranges, precisions, and data rates per the estimates in, Figure 11, Figure 12, Figure 13. Figure 11, Figure 12, Figure 13 are graphical statements of the requirements to be enveloped.

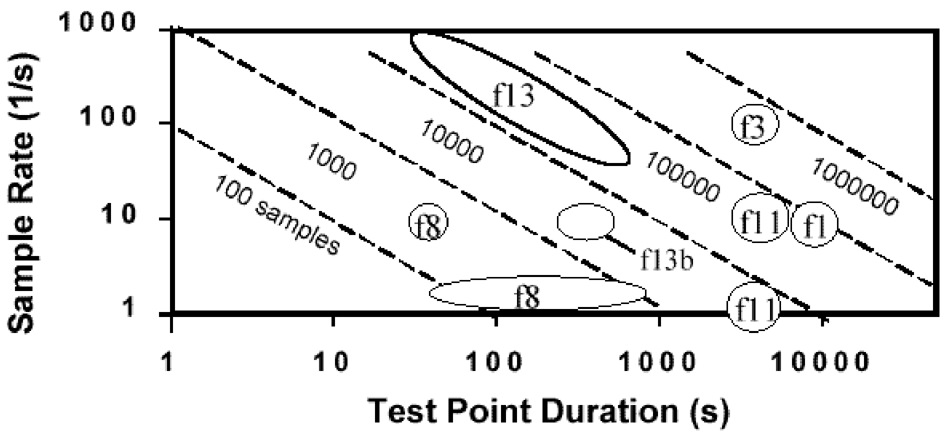


Figure 11. Temperature Measurement Rate and Duration

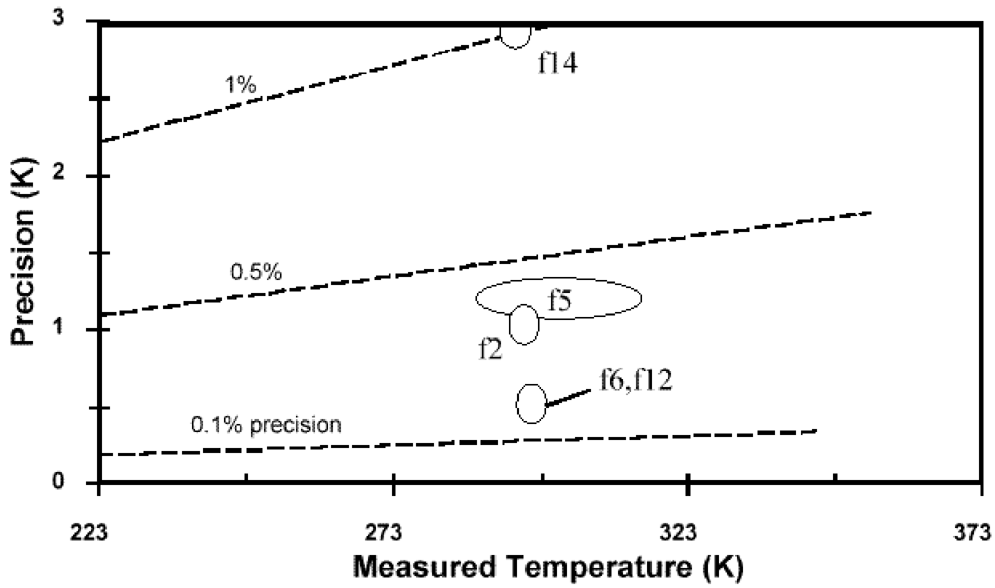


Figure 12. Point Temperature Measurement Precision (Part 1)

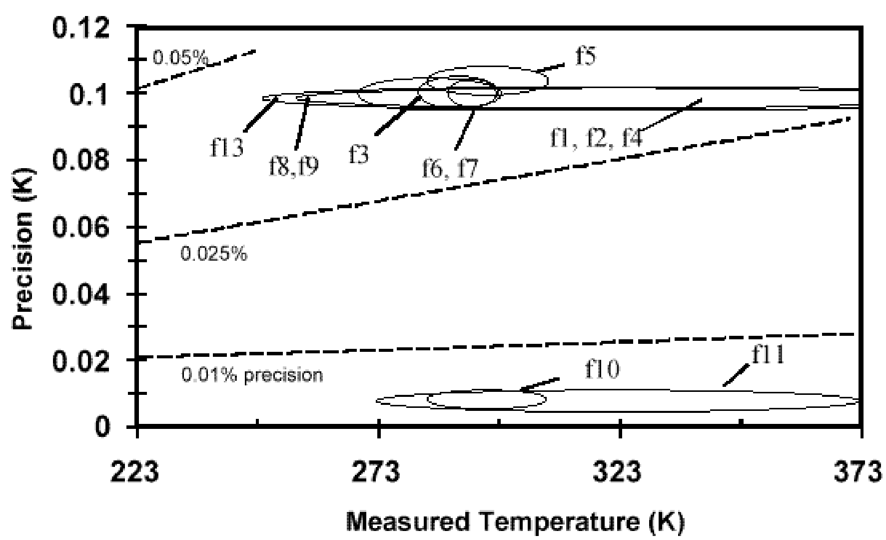


Figure 13. Point Temperature Measurement Precision (Part 2)

3.2.1.26 Identify temperature measurement instrumentation.

a. FIR shall identify temperature measurement instruments or techniques appropriate to the needs of the basis experiments (as implied by Figure 11, Figure 12, Figure 13) and verify their performances. See Appendix G.13 for exception to this requirement.
b. The transducer specifications, test information, and samples shall be made available to PI hardware developers. See Appendix G.13 for exception to this requirement.

3.2.1.27 Acquire and Store Pressure Data.

FIR shall be capable of accommodating acquisition and storage of pressure data at various ranges, precisions, and data rates per the estimates in Figure 14 and Figure 15. Figure 14 and Figure 15 are graphical statements of the requirements to be enveloped.

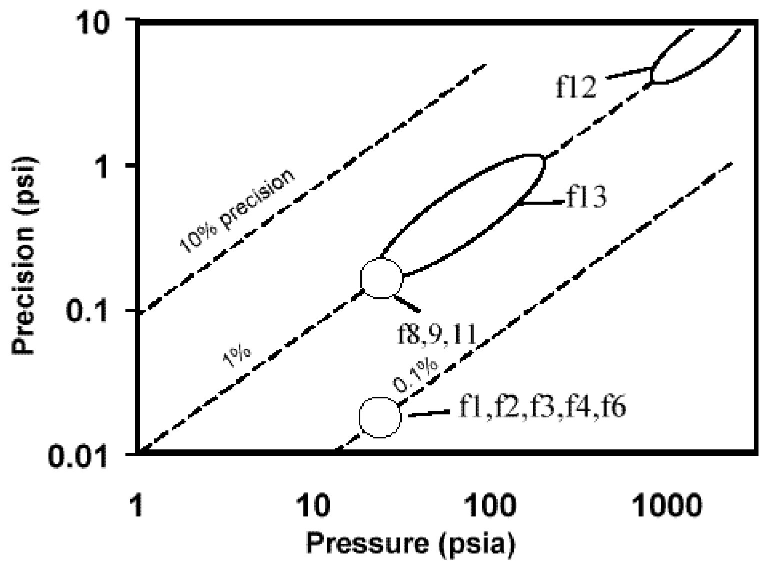


Figure 14. Pressure Measurement Precision

3.2.1.27.1 Ambient Pressure Measurement

The FIR shall provide measurement of the ambient pressure with an accuracy of ± 1%.

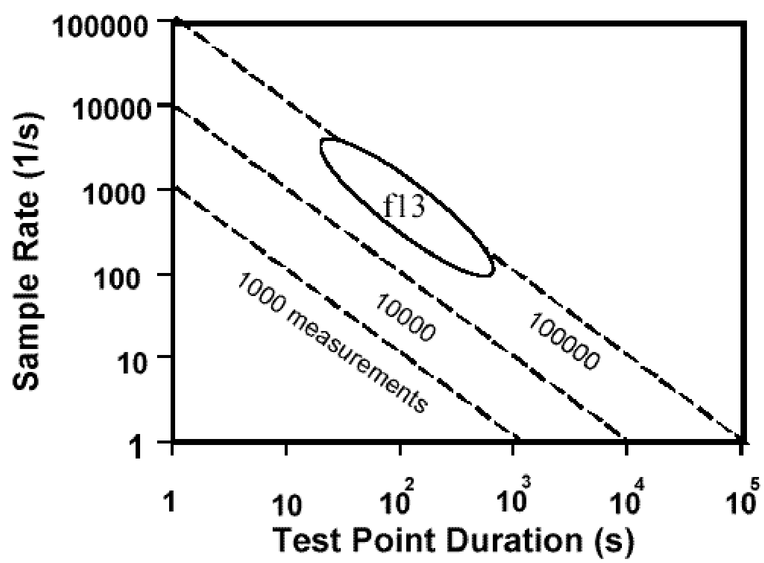


Figure 15. Pressure Measurement Rate and Duration

3.2.1.28 Identify Pressure Measurement Instrumentation.

a. FIR shall identify pressure measurement instruments or techniques appropriate to the needs of the basis experiments (as implied by Figure 14 and Figure 15) and verify their performance. See Appendix G.13 for exception to this requirement.
b. The transducer specifications, test information, and samples shall be made available to PI hardware developers. See Appendix G.13 for exception to this requirement.

3.2.1.29 Acquire and Store Force Data

FIR shall be capable of accommodating acquisition and storage of force at various ranges, precisions, and data rates per the estimates in Figure 16 and Figure 17. Figure 16 and Figure 17 are graphical statements of the requirements to be enveloped.

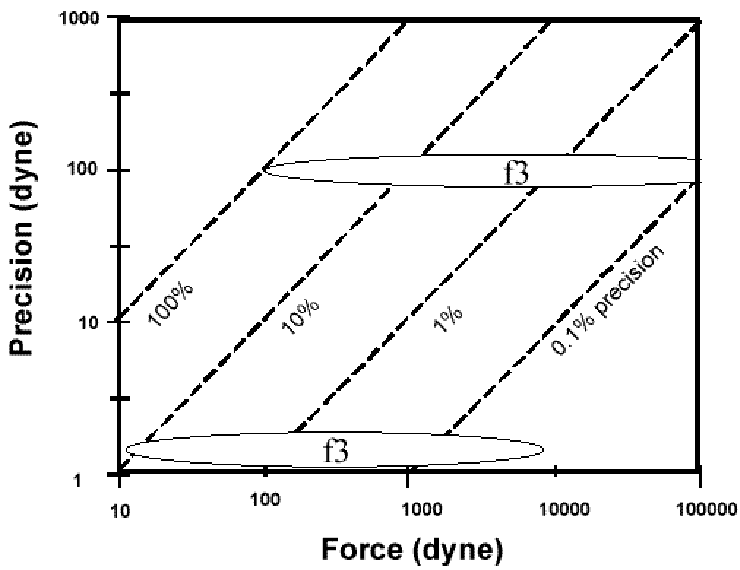


Figure 16. Force Measurement Precision

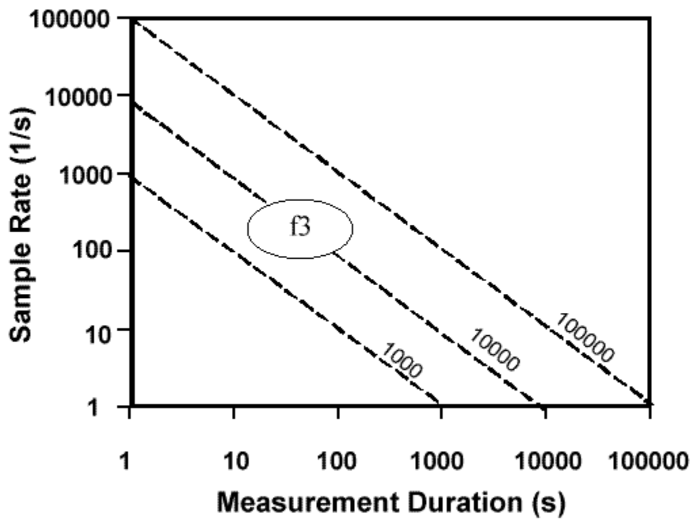


Figure 17. Force Measurement Rate and Duration

3.2.1.30 Identify Force Measurement Instrumentation

a. FIR shall identify force measurement instruments or techniques appropriate to the needs of the basis experiments (as implied by in Figure 16 and Figure 17) and verify their performance. See Appendix G.13 for exception to this requirement.
b. The transducer specifications, test information, and samples shall be made available to PI hardware developers. See Appendix G.13 for exception to this requirement.

3.2.1.31 Acquire and Store Voltage Data.

FIR shall be capable of accommodating acquisition and storage of voltage data at various ranges, precisions, and data rates per the estimates in Figure 18 and Figure 19. Figure 18 and Figure 19 are graphical statements of the requirements to be enveloped.

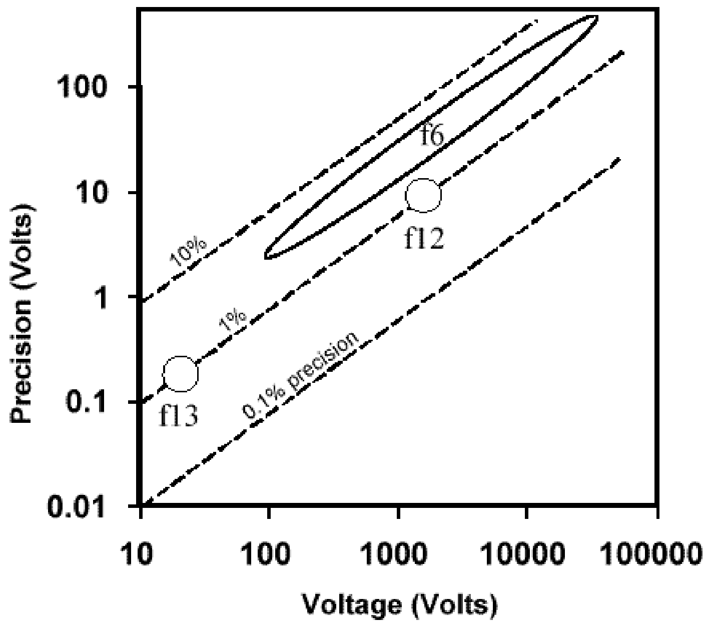


Figure 18. Voltage Measurement Precision

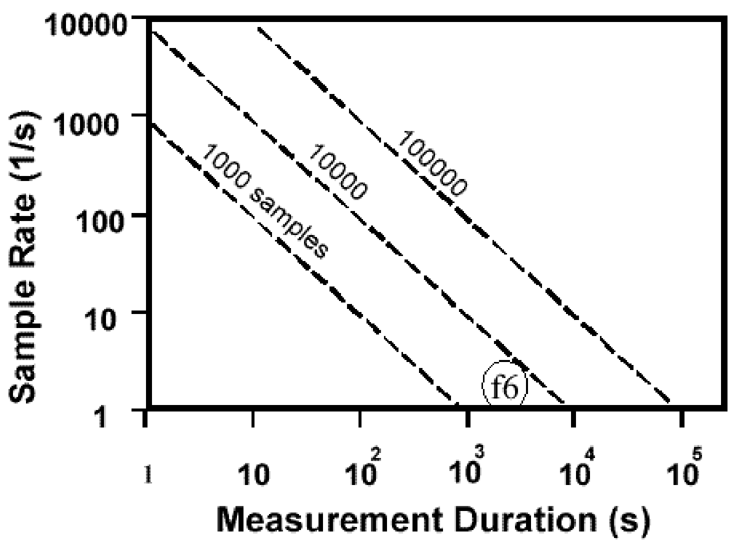


Figure 19. Voltage Sampling Rate and Measurement Duration

3.2.1.32 Identify voltage measurement instrumentation.

a. FIR shall identify voltage measurement instruments or techniques appropriate to the needs of the basis experiments (as implied by Figure 18 and Figure 19) and verify their performance. See Appendix G.13 for exception to this requirement.

b. The transducer specifications, test information, and samples shall be made available to PI hardware developers. See Appendix G.13 for exception to this requirement.

3.2.1.33 Acquire analog data.

FIR shall be capable of simultaneously sampling multiple channels of analog signals originating in PI hardware with sampling rates, as required to accommodate the basis experiments. See Appendix G.22 for exception to this requirement.

3.2.1.34 Digital acquisition.

FIR shall be capable of simultaneously sampling multiple channels of digital signals originating in PI hardware, as required to accommodate the basis experiments.

3.2.1.35 Data time stamps (relative to ISS timing signal)

a. FIR shall provide the capability to time tag all data, including video data relative to an ISS provided timing signal.
b. The time tag shall be of equivalent accuracy and precision to the ISS on-board timing signal or as required by the basis experiments, whichever is less stringent.

3.2.1.36 Data time stamps (ISS and FCF timing signal)

a. FIR shall provide the capability to time tag all data relative to an ISS provided clock signal and an FCF provided internal clock signal.
b. The accuracy of the time tag shall be approximately 0.1s.
c. The precision of the time tag shall be approximately 0.01s.

3.2.1.37 Analog output channels

a. FIR shall provide multiple channels of analog output.
b. These channels shall be capable of waveform generation as well as producing point voltage values.
c. The quantity of channels, their accuracy, and their precision shall be adequate to control the basis experiments.
d. At least 16 channels of at least **[12-bit]** analog output resolution shall be provided to experiments that require them. See Appendix G.12 for exception to this requirement.

3.2.1.38 Internal/external triggering

The FIR shall provide internal and external triggering capability to enable the individual experiments to trigger and correlate various events.

3.2.1.39 Digital acquisition

a. FIR shall be capable of simultaneously outputting multiple channels of Transistor-to-Transistor Logic (TTL)-level output signals (nominally 0 to 5 volts) to PI hardware, as required to accommodate the basis experiments. See Appendix G.17 for exception to this requirement.

b. At least **[16]** channels outputting 1-bit at 5 volts shall be provided to experiments that require them. See Appendix G.17 for exception to this requirement

3.2.1.40 Experiment-specific capabilities.

a. FIR shall be able to accommodate experiment specific computer cards (minimum of two card slots) in an FCF computer near the fluid physics work volume.
b. FIR shall be able to accommodate PI software for experiment control and analysis (i.e., accommodate PI hardware and software).

3.2.1.40.1 Photon counters.

a. The FIR shall provide two photon counters with analog or digital output. See Appendix G.14 for exception to this requirement.
b. Radiation shielding for life expectancy shall be provided.
c. The photon counters modules shall have dark noise.

3.2.1.40.2 Correlator.

a. The FIR shall provide a signal processor as a dedicated high-speed hardware correlator. See Appendix G.15 for exception to this requirement.
b. It shall perform auto- and cross-correlation on at least two digital or analog inputs.
c. It shall operate in real-time at 100% efficiency.
d. Minimum performance of the correlator shall be:
1. 160 nm (?) minimum sample time
2. 256 (?) delays for each of two independent channels;
3. 8, 16, and 32-bit modes

3.2.1.41 Image analysis capability.

The FIR shall provide a high performance computing and data-handling capability for onboard image and data processing to enable telescience adaptation of science procedures which actually depend on more data than is feasible to down/up link with the ISS limited bandwidth.

3.2.1.42 On-orbit instrument calibration.

The FIR shall be capable of performing on-orbit calibrations of instruments using standards traceable to the National Institute of Standards and Technology (NIST).

3.2.1.42.1 Replacement of on-orbit instruments.

The FIR instrument hardware not capable of being calibrated on-orbit shall be designed to be replaced with instruments calibrated to standards traceable to NIST.

3.2.1.43 Rack environment monitoring.

The FIR shall be designed to monitor the pressure, temperature, humidity, and acceleration within the FIR rack environment.

3.2.1.44 On-orbit data storage.

The FIR, with applicable PI hardware and software, shall be capable of identifying all on-orbit data as specified in paragraph 3.2.1.13 based on the basis experiments as specified in FCF-DOC-002.

3.2.1.45 On-orbit data collection and transfer.

3.2.1.45.1 Processing and providing data.

a. The FIR shall be capable of interfacing with the ISS to allow all on-orbit data transfer for downlinking to the ground for use by the payload equipment and FCF ground crews and for data archiving prior to SAR deployment.

b. After SAR deployment, the FIR shall acquire, synthesize, and transfer science performance, configuration, status assessment, and message data to the SAR.

c. Prior to deployment of the SAR, during stand-alone operations, and in case of loss of the SAR to ISS communications, the FIR shall acquire, synthesize and present science, performance, configuration, status assessment, and message data to the on-orbit crew in the form of textual and graphic displays to the Station Support Computer (SSC).

d. Prior to SAR deployment and within the limited volume provided for image processing, the FIR shall be capable of processing scientific and engineering data in order to reduce the real-time, near real-time and post-test bandwidth and duration necessary to transmit the data to the ground through the ISS. This processing should allow for 1.) limiting the data streams through selection of duration and downlink sample rates by the FCF ground operations and payload equipment operation teams, for all data streams 2.) downlinking data only when it is above, below, between, or outside a certain value(s) selected by the FCF ground operations and payload equipment operation teams, and 3.) mission specific compression or data manipulation software code to be run. Note that this does not require the mission specific software code to be developed, only the capability to run such code when it is developed.

e. The FIR shall retain all data until commands are received from the FCF ground operations team indicating what data can be deleted or over-written.

f. The FIR shall be capable of providing, when requested by the FCF ground operations team, a summary of all data stored in the FIR, including identification of each measurement, time stamp/duration of data for each measurement, and file sizes.

g. The FIR shall be capable of sending image streams from scientific imaging devices in the FIR to the SAR for image processing and storage.

3.2.1.45.2 On-orbit data transfer within FCF.

The FIR shall be capable of accepting and transferring all data to the SAR up to a rate of 100 Mbits/s after SAR deployment.

3.2.1.45.3 Use of fiber optics.

The FIR shall use fiber optics for transferring all digital image data and inter-rack communications.

3.2.1.45.4 On-orbit data transfer to portable media.

The FIR shall be capable of transferring all stored data, as specified in paragraph 3.2.1.13 based on the basis experiments as specified in FCF-DOC-002, to portable media.

3.2.1.46 FIR health status monitoring.

The FIR, with applicable PI hardware and software, shall be designed to monitor and transfer on-orbit health status data of all assemblies with electrical and fluids interfaces to the Station Support Computer (SSC) and to the SAR and to transfer on-orbit health status data to the ISS for downlinking when the FIR is powered and note any out-of-tolerance conditions.

3.2.1.46.1 FIR/FCF health status monitoring.

The FIR shall have the capability to interface with the SSC, to transfer to the SSC health status data of FCF systems that interface with the FIR, and to transfer the health status data to the ISS for downlinking when the FIR is powered and note any out-of-tolerance conditions.

3.2.1.46.1.1 Health status reporting to SAR.

The FIR shall report all out-of-tolerance conditions to the SAR after SAR deployment.

3.2.1.46.2 FIR/ISS health status monitoring.

The FIR shall have the capability to interface with the SSC, to transfer to the SSC its health status data of ISS systems that interface with the FIR, and to transfer the health status data to the ISS for downlinking when the FIR is powered and note any out-of-tolerance conditions.

3.2.1.47 FIR Commanding.

3.2.1.47.1 SSC Commanding.

The FIR, with applicable PI hardware and software, shall be capable of accepting command inputs, acknowledging and validating the inputs, returning responses, and monitoring all FIR functions that use the SSC when the FIR is powered.

3.2.1.47.2 Ground Commanding.

The FIR, with applicable PI hardware and software, shall be capable of accepting command inputs, acknowledging and validating the inputs, and returning responses through the ISS-provided interfaces when the FIR is powered.

3.2.1.47.3 Commanding through SAR.

The FIR, with applicable PI hardware and software, shall be capable of accepting command inputs, acknowledging and validating the inputs, and returning responses using the SAR when the FIR is powered.

3.2.1.47.4 Manual Inputs

The FIR shall provide the mechanical (switches, displays, etc.) equipment necessary for the on-orbit crew to control the FIR.

3.2.1.48 Upgrading of FIR maintenance items.

The FIR shall be designed to allow for upgrading of components within the assemblies and other maintenance items within the FIR.

3.2.1.49 Use of CIR capabilities.

The FIR shall investigate the use of CIR capabilities to meet science and project requirements.

3.2.1.50 Control of FIR.

a. The FIR shall provide overall control as specified in Table III.

Table III. Control Conditions

Capability	Control Conditions
Perform/support fluid physics science	Capability is not required to be continuous. Initiation of capability shall be through ground or on-orbit crew command.
Process and provide data	Capability is not required to be continuous. Initiation of capability shall be through automated sequence or

	ground or on-orbit crew command.
Respond to out-of-tolerance conditions	Capability is required to be continuous, whenever powered.
Withstand external environment changes	Capability is required to be continuous.
Accept commanding and manual inputs	Capability is required to be continuous, whenever powered.
Maintenance/troubleshooting	Capability is not required to be continuous. Initiation of capability shall be through ground or on-orbit crew command or on-orbit crew operation.
Reconfigure FIR	Capability is not required to be continuous. Initiation of capability shall be through ground or on-orbit crew command for software and on-orbit crew operation for hardware.

b. The FIR shall control all payload equipment placed within the FIR.

3.2.2 Physical characteristics.

3.2.2.1 FIR dimensional characteristics.

3.2.2.1.1 FIR launch envelope.

The FIR in launch configuration shall not exceed the envelope as specified in SSP 41017 Part 1, paragraph 3.2.1.1.2.

3.2.2.1.2 FIR on-orbit envelope.

The FIR, with applicable PI hardware, shall have an on-orbit envelope as specified in SSP 41017 Part 1, paragraph 3.2.1.1.2 and shall follow the on-orbit payload protrusion requirements as specified in SSP 57000, paragraph 3.1.1.7. See Appendix G.3 for exceptions to this requirement.

3.2.2.1.3 FIR stowage volume.

a. The FIR, with applicable PI hardware, shall not exceed a stowage volume of 1 standard rack equivalent.
b. The FIR shall provide a minimum of 0.45 m^3 of space for payload equipment within its envelope with an additional 0.60 m^3 of optionally available for use by payloads if they do not require FIR provided diagnostics. See Appendix G.9 for exception to this requirement.

3.2.2.1.4 FIR maintenance item stowage.

The FIR maintenance items shall not exceed a volume of 1/3 standard rack equivalents, including packaging, per year.

3.2.2.2 FIR weight characteristics.

c. The FIR shall not exceed a launch mass of 804.2 kg (1773 lbs.), excluding stowage hardware.
d. The FIR, with applicable PI hardware, shall not exceed an on-orbit mass of 804.2 kg (1773 lbs.), excluding stowage hardware.
c. FIR spares and resupply equipment shall not exceed an up-mass of 125 kg (275 lbs.), including packaging, per year.

3.2.2.3 FIR power.

a. The FIR, with applicable PI hardware, shall have the capability to use a maximum of 6,000 W of power.
b. The FIR, with applicable PI hardware, when integrated into the FCF, shall not exceed a power draw of <TBD 03-06> W.

3.2.2.3.1 FIR environmental control system power allocation.

The FIR environmental control system power allocation shall not exceed, over a period of 30 minutes, 30 W or 8% of the input power to the FIR, whichever is greater. See Appendix G.18 for exception to this requirement.

3.2.2.3.2 FIR power to PI hardware.

a. FCF shall provide PI-provided experiment payload with adequate power per the estimates shown in Figure 20.
b. At a minimum, this power shall be 500 W for a period of weeks (when needed) and 1000 W for periods of at least 15 minutes (when needed). Figure 20 is a graphical statement of the requirements.
c. FIR shall provide a minimum of 5 individually controlled sources of electric power (28 Vdc, 4A circuits) for use by PI experiment payload.
d. FIR shall provide a source of 120 Vdc power, in addition to 28 Vdc, for use by experiments.

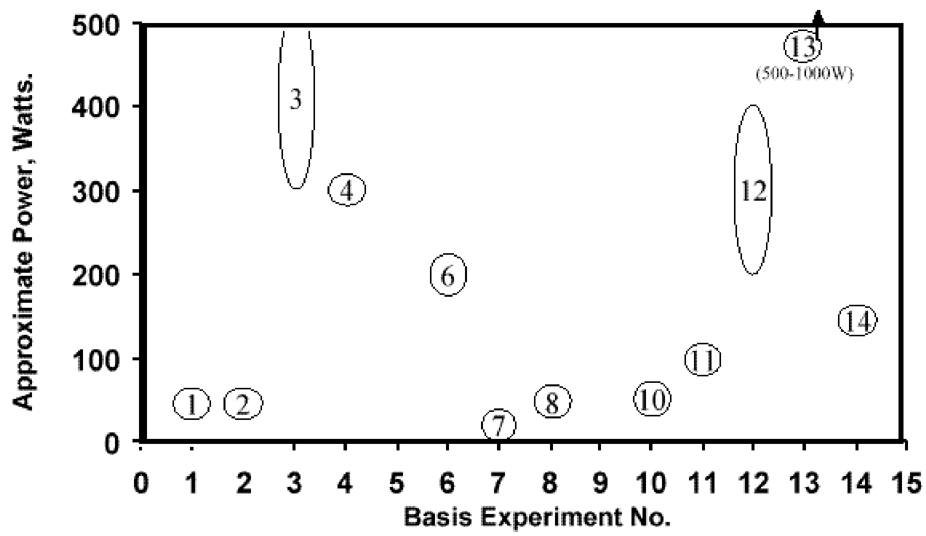


Figure 20. Power Requirements for the Basis Experiments

3.2.2.3.3 Provide experiment access to cooling media

a. FIR shall provide PI experiment payload with easy access to cooling adequate to dissipate the power provided to the PI hardware.
b. Access to both liquid-cooling and air-cooling is required.

3.2.2.4 FIR heat rejection.

The FIR shall reject heat to the ISS MTL, consistent with overall rack electrical power consumption, in order to maintain facility and PI hardware within acceptable temperature limits.

3.2.2.5 PI air cooling .

The FIR shall provide a minimum of 459 watts of air cooling to the payload hardware.

3.2.2.6 Thermal cooling water.

FIR, with applicable PI hardware, shall be capable of providing thermal water cooling with a minimum inlet temperature of 16.1°C (61.0°F) and a maximum outlet temperature of 48.9°C (120°F).

3.2.2.6.1 PI water cooling

The FIR shall provide a minimum of 500 watts of water cooling to the PI hardware.

3.2.2.7 Durability.

a. The FIR shall be designed to have a minimum operational life of 10 years after full deployment of the FCF, including regular scheduled and unscheduled maintenance activities.
b. The FIR shall be designed to be capable of an extended life to 15 years after full deployment, including regular scheduled and unscheduled maintenance activities and major component replacement.

3.2.2.8 Transportation and safety requirements.

This paragraph is covered in paragraph 3.2.7 and section 5.

3.2.2.9 Interfaces.

The FIR, with applicable PI hardware, shall interface with the ISS and FIR internal assemblies in accordance with paragraph 3.1.5.

3.2.2.9.1 Ground support equipment (GSE) interfaces.

a. The FIR shall interface to the Kennedy Space Center (KSC) GSE Rack Insertion Device in accordance with SSP 41017 Part 1, paragraphs 3.2.1.1.2 and 3.2.1.4.3 and SSP 41017 Part 2, paragraphs 3.3.2 and 3.3.3.
b. The FIR shall interface to Rack Shipping Containers in accordance with the Teledyne Brown Engineering (TBE) as-built drawing 220G07500.
c. The FIR shall interface to Rack Handling Adapters (RHA) in accordance with the following TBE as-built drawings: 220G07455, 220G07470, and 220G07475.
d. The FIR shall be limited to ground transportation accelerations of 80% of flight accelerations defined by SSP 41017 Part 1, paragraph 3.2.1.4.2.

3.2.2.9.2 MPLM interfaces.

a. The FIR shall interface to the MPLM structural attach points in accordance with SSP 41017 Part 2, paragraph 3.1.1.
b. The FIR shall maintain positive margins of safety for MPLM depress rates of 890 Pa/s (7.75 psi/min) and repress rates of 800 Pa/s (6.96 psi/min).
c. The FIR shall be limited to producing interface attach point loads less than or equal to those identified by SSP 41017 Part 1, paragraph 3.2.1.4.3, based upon an acceleration environment as defined in SSP 41017 Part 1, paragraph 3.2.1.4.2.

3.2.2.9.3 COF interfaces.

The FIR shall be capable of interfacing with the COF for structural, fluids, and electrical connections, but shall not be required to meet any of the performance requirements and physical requirements unless otherwise specified in SSP 57000.

3.2.2.10 Glove box type access.

a. The FIR shall provide the capability to add glove box type access, on orbit, to payloads anywhere on the front of the optics bench.
b. The glove box access shall allow manipulation of the payload, while leaving the rack doors closed and the rack powered. Such capability includes the ability to have a clear visual access of the work area accessible by the gloves.
c. The glove box equipment will be a FCF upgrade, payload equipment or a combination of these.

3.2.2.11 Experiment containment.

a. The FI shall not preclude the mounting of a sealed container, up to the size of a double middeck locker, to the front of the optics bench. See Appendix G.4 for exception to this requirement.
b. The sealed container shall have pass throughs to accommodate fluids/gas, optical and/or electric connectors.

3.2.3 Reliability.

Not applicable.

3.2.4 Maintainability.

The FIR shall not exceed <TBD 03-07> on-orbit mean maintenance crew hours per year (MMCH/Y) for scheduled and unscheduled maintenance activities including inspections, preventative and corrective maintenance, restorations, and replacement of assemblies and components.

3.2.4.1 FIR maintenance access.

The FIR shall be designed to allow for the replacement of Orbital Replacement Units (ORUs) and failed components and the performance of other internal maintenance activities without rotating the FIR from its installed position within the US Lab. See Appendix G.2 for exceptions to this requirement.

3.2.4.2 Maintenance item temporary restraint and stowage.

FIR maintenance items shall be designed to allow for temporary restraint and/or stowage during maintenance activities.

3.2.4.3 Tool usage for maintenance.

The FIR shall be designed to be maintained using the ISS tools as defined in SSP 57020.

3.2.4.4 Lockwiring and staking.

All FIR maintenance items shall not be lockwired or staked during installation.

3.2.4.5 Redundant paths.

The FIR, with applicable PI hardware, shall be designed to provide for alternate or redundant functional paths of all electrical and electronic harnesses that cannot be replaced on-orbit.

3.2.4.6 FIR reconfiguration for out-of-tolerance conditions.

The FIR, with applicable PI hardware, shall be designed to allow visual and tactile access to all avionics hardware for at least one hour during troubleshooting operations without detrimental effects to the crew, the ISS, or FIR hardware.

3.2.5 Availability.

The FIR, with applicable PI hardware and spares, shall have an operational availability of <TBD 03-02> for a base operational life of 10 years with an extendable capability to 15 years in accordance with the formula:

A_0 = MTBM/MTBM+MDT

Where MTBM = Mean Time Between Maintenance and MDT = Mean Delay Time.

3.2.6 Environmental conditions.

3.2.6.1 Shipping and storage environment.

3.2.6.1.1 Nonoperating atmospheric environment.

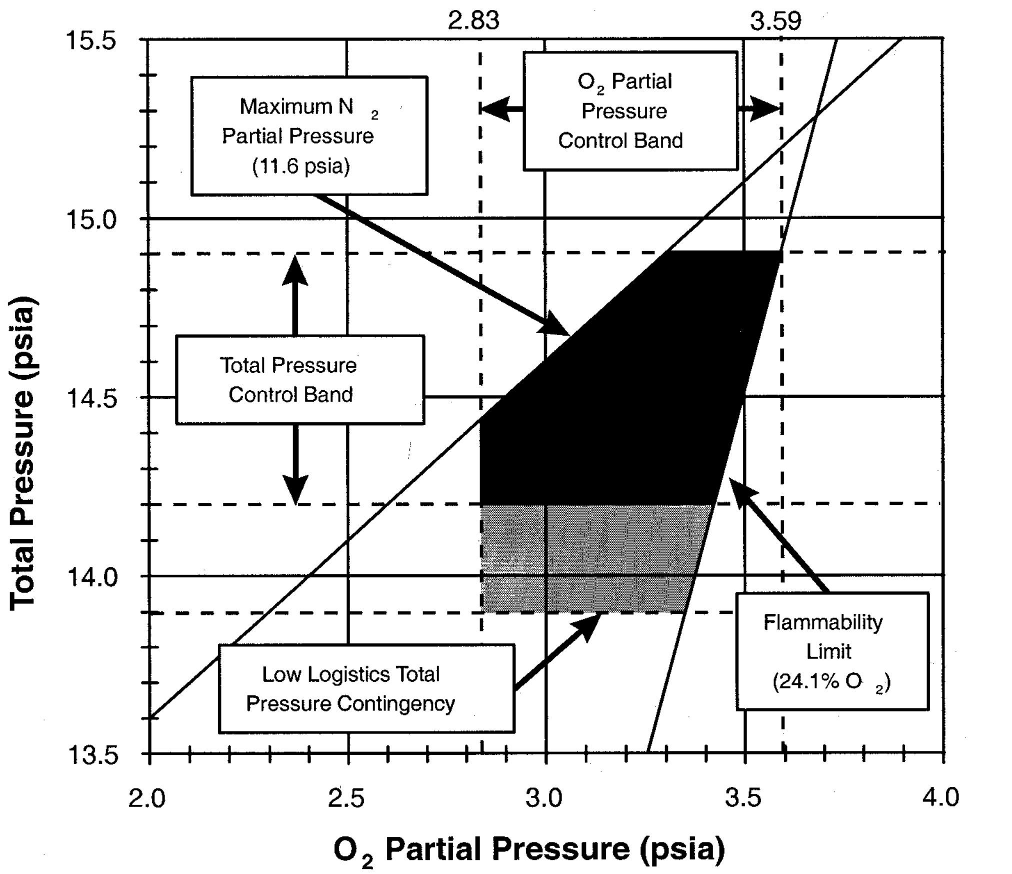
a. The FIR shall be designed to have a nonoperating temperature range from 2 to 50°C (35.6 to 122°F).
b. The FIR shall be designed to have a nonoperating pressure range from 0 to 104.8 kPa.
c. The FIR shall be designed to tolerate a relative humidity range from 10 to 90%.

3.2.6.2 MPLM/on-orbit environmental conditions.

The FIR, with the applicable PI hardware, shall meet the MPLM/on-orbit environmental conditions as specified in Table IV.

Table IV. MPLM/on-orbit environmental conditions

3.2.6.2.1 Environmental Condition	Value	
Atmospheric Conditions on ISS		
Pressure Extremes	0 to 104.8 kPa (0 to 15.2 psia)	
Normal operating pressure	See Figure 21	
Oxygen partial pressure	See Figure 21	
Nitrogen partial pressure	See Figure 21	
Dewpoint	4.4 to 15.6°C (40 to 60°F) ref. Figure 22	
Percent relative humidity	25 to 75% ref. Figure 22	
Carbon dioxide partial pressure during normal operations with 6 crewmembers plus animals	24-hr average exposure 5.3 mm Hg Peak exposure 7.6 mm Hg	
Carbon dioxide partial pressure during crew changeout with 11 crewmembers plus animals	24-hr average exposure 7.6 mm Hg Peak exposure 10 mm Hg	
Cabin air temperature in USL, JEM, APM, and CAM	17 to 28°C (63 to 82°F)	
Cabin air temperature in Node 1	17 to 31°C (63 to 87°F)	
Air velocity (Nominal)	0.051 to 0.203 m/s (10 to 40 ft/min)	
Airborne microbes	Less than 1000 CFU/m3	
Atmosphere particulate level	Average less than 100,000 particles/ft3 for particles less than 0.5 microns in size	
MPLM Air Temperatures	**Passive Flights**	**Active Flights**
Pre-Launch	15 to 24°C (59 to 75.2°F)	14 to 30°C (57.2 to 86°F)
Launch/Ascent	14 to 24°C (57.2 to 75.2°F)	20 to 30°C (68 to 86°F)
On-orbit (Cargo Bay + Deployment)	24 to 44°C (75.2 to 111.2°F)	16 to 46°C (60.8 to 114.8°F)
On-orbit (On-Station)	23 to 45°C (73.4 to 113°F)	16 to 43°C (60.8 to 109.4°F)
On-orbit (Retrieval + Cargo Bay)	17 to 44°C (62.6 to 111.2°F)	11 to 45°C (51.8 to 113°F)
Descent/Landing	13 to 43°C (55.4 to 109.4°F)	10 to 42°C (50 to 107.6°F)
Post-Landing	13 to 43°C (55.4 to 109.4°F)	10 to 42°C (50 to 107.6°F)
Ferry Flight	15.5 to 30°C (59.9 to 86°F)	15.5 to 30°C (59.9 to 86°F)
MPLM Maximum Dewpoint Temperatures		
Pre-Launch	13.8°C (56.8°F)	12.5°C (54.5°F)
Launch/Ascent	13.8°C (56.8°F)	12.5°C (54.5°F)
On-orbit (Cargo Bay + Deployment)	13.8°C (56.8°F)	12.5°C (54.5°F)
On-orbit (On-Station)	15.5°C (60°F)	15.5°C (60°F)
On-orbit (Retrieval + Cargo Bay)	10°C (50°F)	10°C (50°F)
Descent/Landing	10°C (50°F)	10°C (50°F)
Post-Landing	10°C (50°F)	10°C (50°F)
Ferry Flight	15.5°C (60°F)	15.5°C (60°F)
Thermal Conditions		
USL module wall temperature	13°C to 43°C (55°F to 109°F)	
JEM module wall temperature	13°C to 45°C (55°F to 113°F)	
APM module wall temperature	13°C to 43°C (55°F to 109°F) (TBR #4)	
CAM module wall temperature	13°C to 43°C (55°F to 109°F) (TBR #5)	
Other integrated payload racks	Front surface less than 37°C (98.6°F)	
*** Microgravity**		
Quasi-Steady State Environment	See Figure 23, Figure 24, and Table V	
Vibro-acoustic Environment	See Figure 25	
General Illumination	108 Lux (10 fc) measured 30 inches from the floor in the center of the aisle	



* Note: Data reflects best available information as of May, 1997. Does not include effects of CAM.

Figure 21. Operating limits of the ISS atmospheric total pressure, nitrogen, and oxygen partial pressures

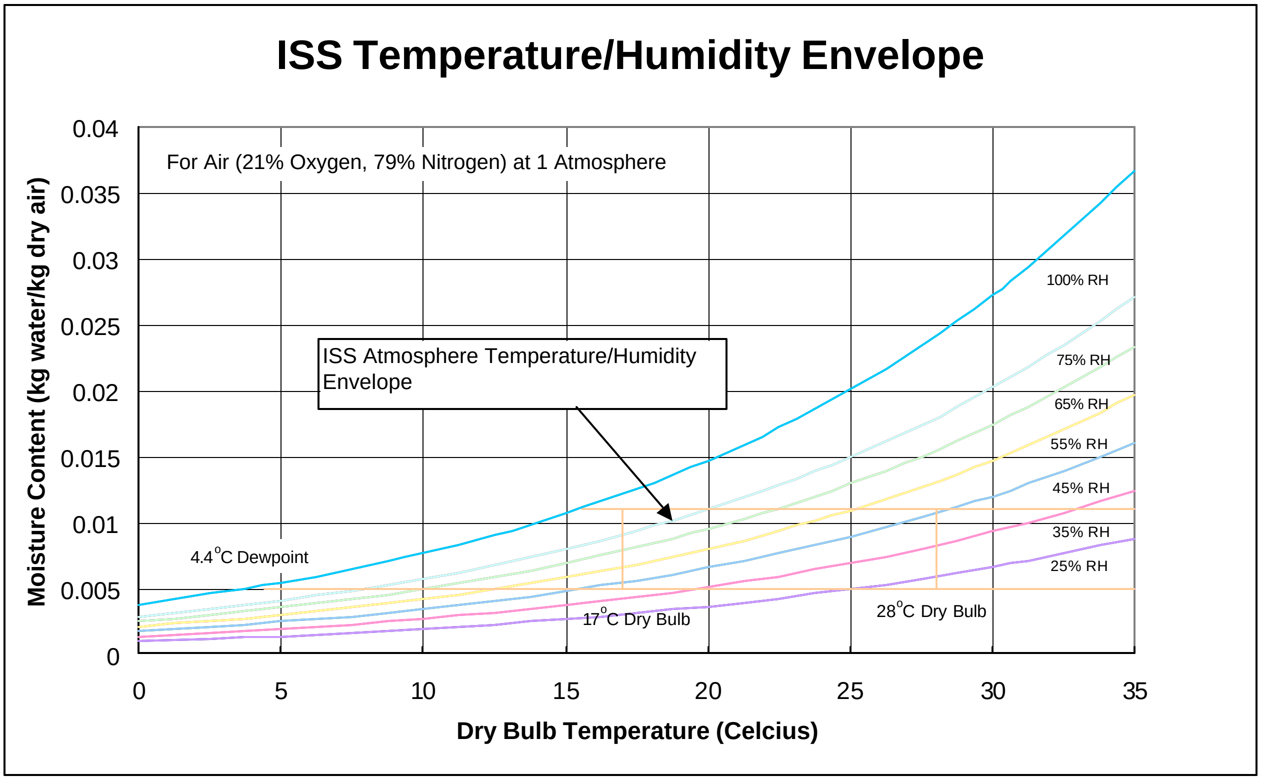


Figure 22. ISS temperature/humidity envelope

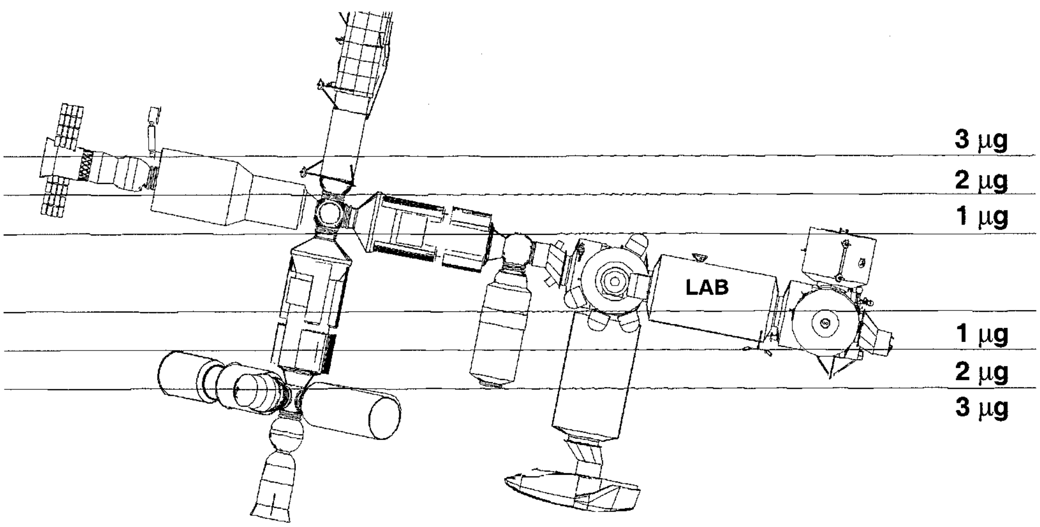


Figure 23. Assembly complete quasi-steady state microgravity contours (side)

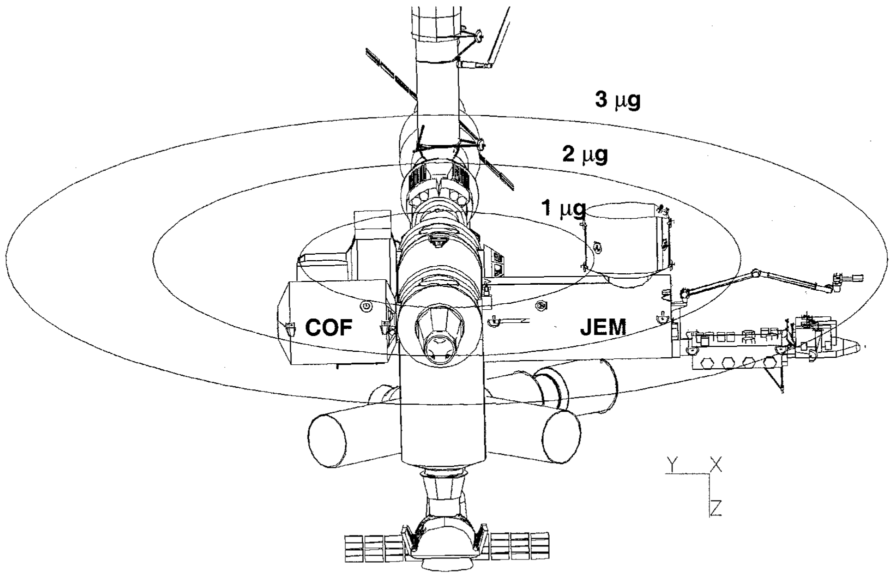


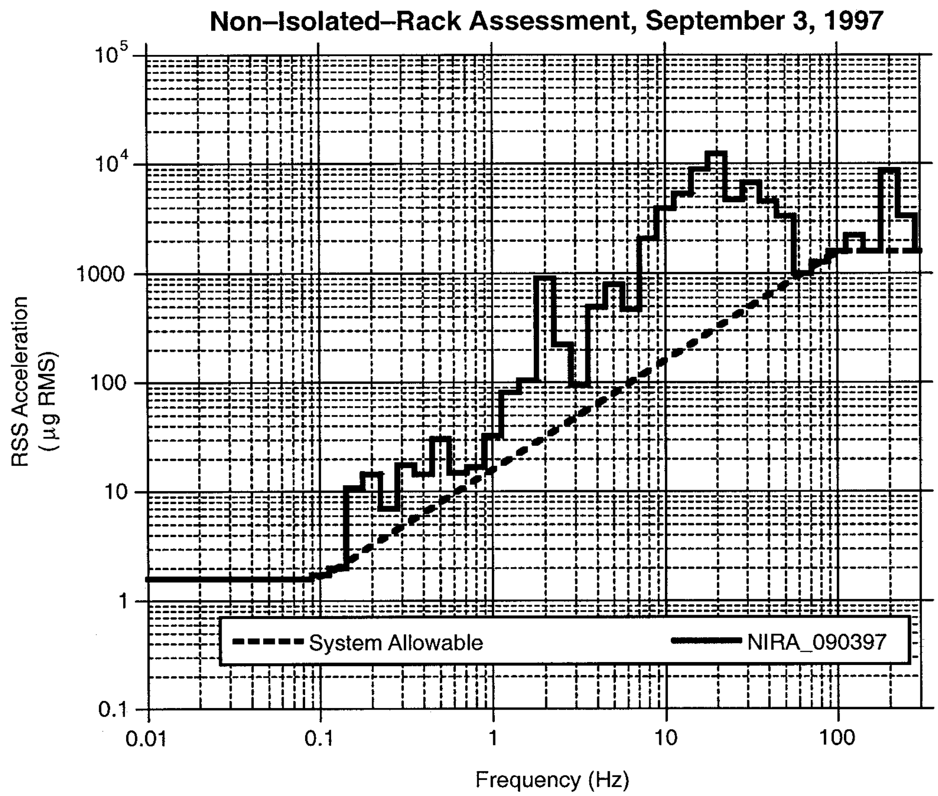
Figure 24. Assembly complete quasi-steady state microgravity contours (front)

Table V. Assembly complete quasi-steady state microgravity environment

Location	Magnitude	Stability	Unit Vector Components			Angle
(ISPRs)	(μg)	(μg)	X	Y	Z	(deg)
USL–C1	**0.525**	0.126	0.641	–0.109	0.760	17.370
USL–C2	**0.468**	0.116	0.721	–0.133	0.680	20.710
USL–C3	**0.419**	0.100	0.819	–0.165	0.549	24.820
USL–C4	**0.380**	0.078	0.922	–0.204	0.330	28.370
USL–C5	**0.356**	0.064	0.972	–0.237	–0.002	25.280
USL–S1	1.062	0.145	0.385	–0.227	0.895	7.927
USL–S2	**0.989**	0.143	0.400	–0.248	0.883	8.421
USL–S3	**0.917**	0.141	0.417	–0.272	0.867	8.973
USL–S4	**0.846**	0.138	0.437	–0.300	0.848	9.859
USL–P1	1.019	0.145	0.396	0.166	0.903	8.310
USL–P2	**0.945**	0.143	0.413	0.180	0.893	8.866
USL–P4	**0.799**	0.138	0.458	0.215	0.862	10.230
JPM1–A1	1.250	0.150	0.348	0.333	0.877	7.015
JPM2–F1	1.480	0.154	0.325	0.282	0.903	6.095
JPM3–A2	1.296	0.151	0.334	0.433	0.838	6.819
JPM4–F2	1.519	0.154	0.316	0.370	0.874	5.979
JPM5–A3	1.355	0.151	0.318	0.520	0.793	6.570
JPM6–F3	1.569	0.155	0.305	0.450	0.839	5.824
JPM7–A4	1.425	0.152	0.301	0.594	0.746	6.288
JPM8–A5	1.505	0.153	0.284	0.657	0.699	5.992
JPM9–F5	1.700	0.156	0.280	0.584	0.762	5.441
JPM10–F6	1.778	0.157	0.266	0.638	0.723	5.234
APM–FWD1	1.605	0.155	0.305	–0.386	0.871	5.573
APM–FWD2	1.681	0.157	0.291	–0.465	0.836	5.370
APM–FWD3	1.768	0.159	0.277	–0.532	0.800	5.167
APM–FWD4	1.863	0.161	0.263	–0.590	0.763	4.968
APM–AFT1	1.397	0.152	0.318	–0.451	0.834	6.275
APM–AFT2	1.482	0.154	0.300	–0.534	0.791	5.989
APM–AFT3	1.578	0.157	0.282	–0.603	0.747	5.709
APM–AFT4	1.682	0.160	0.264	–0.659	0.704	5.450

Location	Magnitude	Stability	Unit Vector Components			Angle
(Others)	(μg)	(μg)	X	Y	Z	(deg)
USL–CG	0.793	0.137	0.466	–0.052	0.883	10.360
APM–CG	1.624	0.157	0.288	–0.533	0.795	5.547
APM–CLG1	1.010	0.151	0.350	–0.649	0.676	8.635
APM–CLG2	1.120	0.154	0.313	–0.726	0.612	7.944
RS–FGB	1.119	0.139	–0.003	–0.060	–0.998	7.802
RS–SM	2.179	0.129	–0.099	–0.038	–0.994	3.655
JEM–CG	1.811	0.157	0.244	0.745	0.621	5.143
JEF1–F1	2.954	0.165	0.223	0.627	0.746	3.325
JEF2–A1	2.613	0.160	0.218	0.706	0.674	3.646
JEF3–F2	3.039	0.167	0.216	0.658	0.722	3.265
JEF4–A2	2.710	0.162	0.209	0.734	0.646	3.558
JEF5–F3	3.129	0.169	0.209	0.685	0.698	3.208
JEF6–A3	2.811	0.164	0.201	0.760	0.619	3.477
JEF7–F4	3.223	0.171	0.203	0.710	0.674	3.155
JEF8–A4	2.915	0.167	0.194	0.782	0.593	3.401
JEF9–O1	3.303	0.174	0.188	0.771	0.608	3.135
JEF10–O2	3.091	0.174	0.174	0.838	0.517	3.334
JEF11–U1	2.456	0.169	0.184	0.861	0.474	4.064
JEF12–U2	2.553	0.171	0.170	0.890	0.423	3.955
S3LO	3.299	0.223	0.038	–0.994	–0.104	3.918
S3LI	2.945	0.212	0.042	–0.991	–0.124	4.180
S3UO	3.958	0.209	–0.056	–0.846	–0.530	3.142
S3UI	3.644	0.196	–0.062	–0.810	–0.584	3.222
P3LO	3.260	0.191	0.022	0.973	–0.231	3.355
P3UO	4.043	0.176	–0.068	0.780	–0.622	2.494

10 ISPRs Have Quasi–Steady Magnitude </= 1.0 g



Note: The Non-Isolated Rack Assessment (NIRA) is a prediction of the "vehicle induced", Assembly Complete, acceleration environment at non-isolated ISPRs during microgravity mode. The acceleration environment depicted represents a 100 second, root-mean-square average per one-third octave band from 0.01 to 300 Hz at the rack to module structural interfaces. It is intended to represent the enveloped acceleration response over all the non-isolated ISPR locations in the U.S. Lab, JEM, and APM. The NIRA is based on the DAC–4 ISS assessment of vehicle microgravity compliance which computed the acceleration response to all significant U.S. and Russian segment disturbance sources. To account for the ESA and NASDA disturbance sources, the NIRA at this time assumes that the acceleration responses produced by the ESA and NASDA disturbances are equivalent to the responses produced by the U.S. Lab, Hab, and Airlock disturbances combined less exercise equipment. A similar assumption is also used to account for the CAM in this NIRA. Thus, with these assumptions, the NIRA accounts for all "vehicle induced" accelerations during microgravity mode. The NIRA does not account for "payload induced" accelerations nor "crew induced" accelerations, other than those produced by the crew when using exercise devices. The NIRA is expected to be updated as improved predictions become available.

Figure 25. Assembly complete vibratory environment

3.2.6.3 On-orbit condensation.

The FIR shall be designed to not cause condensation when exposed to the ISS atmosphere ranging in dewpoint from 4.4 to 15.6°C (40 to 60°F) and in relative humidity from 25 to 75%.

3.2.6.4 Special environmental conditions.

3.2.6.4.1 Load requirements.

a. The FIR shall provide positive margins of safety for launch and landing load conditions in the MPLM based upon an acceleration environment as defined in SSP 41017 Part 1, paragraph 3.2.1.4.2. Loads should be consistently applied with the rack coordinate system defined in SSP 41017 Part 2, paragraph 3.1.3.
b. The FIR shall provide positive margins of safety for on-orbit loads of 0.2 g acting in any direction.
c. Rack Utility Panel (RUP) umbilicals shall be restrained during launch and landing to prevent damage to loose connectors from loads and vibration.
d. FIR equipment shall provide positive margins of safety when exposed to the crew-induced loads defined in Table VI.
e. For design and qualification purposes, components mounted to ISPR posts shall maintain positive margins of safety for the MPLM launch random vibration environment as defined in Table VII or Table VIII.
f. Components mounted to the ISPR shall maintain positive margins of safety for the launch and landing conditions in the MPLM. For early design, the acceleration environment defined in Table IX will be used. These load factors will be superseded by load factors obtained through an ISS-performed coupled loads analysis as described in SSP 52005.

Table VI. Crew-induced loads

CREW SYSTEM OR STRUCTURE	TYPE OF LOAD	LOAD	DIRECTION OF LOAD
Levers, Handles, Operating Wheels, Controls	Push or Pull concentrated on most extreme edge	222.6 N (50 lbf), limit	Any direction
Small Knobs	Twist (torsion)	14.9 N–m (11 ft-lbf), limit	Either direction
Exposed Utility Lines (Gas, Fluid, and Vacuum)	Push or Pull	222.6 N (50 lbf)	Any direction
Rack front panels and any other normally exposed equipment	Load distributed over a 4 inch by 4 inch area	556.4 N (125 lbf), limit	Any direction
Legend: ft = feet, m = meter, N = Newton, lbf = pounds force			

Table VII. Random vibration criteria for ISPR post-mounted equipment weighing 100 pounds or less in the MPLM

FREQUENCY	LEVEL
20 Hz	0.005 g^2/Hz
20–70 Hz	+ 5.0 dB/oct
70–200 Hz	0.04 g^2/Hz
200–2000 Hz	–3.9 dB/oct
2000 Hz	0.002 g^2/Hz
Composite	4.4 grms
Note: Criteria is the same for all directions (X,Y,Z)	

Table VIII. Random vibration criteria for ISPR post-mounted equipment weighing more than 100 pounds in the MPLM

FREQUENCY	LEVEL
20 Hz	0.002 g2/Hz
20–70 Hz	+ 4.8 dB/oct
70–200 Hz	0.015 g2/Hz
200–2000 Hz	–3.7 dB/oct
2000 Hz	0.0006 g2/Hz
Composite	2.4 grms
Note: Criteria is the same for all directions (X,Y,Z)	

Table IX. Payload ISPR mounted equipment load factors (equipment frequency 35 Hz)

Liftoff	X	Y	Z
(g)	± 7.7	± 11.6	± 9.9
Landing	**X**	**Y**	**Z**
(g)	± 5.4	± 7.7	± 8.8
Note: Load factors apply concurrently in all possible combinations for each event and are shown in the rack coordinate system defined in SSP 41017, Part 2, paragraph 3.1.3.			

3.2.6.4.2 Rack requirements.

a. The FIR shall maintain positive margins of safety for the on-orbit depress/repress rates identified in SSP 41002, paragraph 3.1.7.2.1.
b. The FIR and kneebrace shall have a modal frequency in accordance with SSP 52005, paragraph 5.7, second paragraph for launch and landing, based on rigidly mounting the integrated rack in the launch configuration.
c. Equipment mounted directly to the FIR ISPR will have a modal frequency goal of 35 Hz for launch and landing, based on rigidly mounting the component at the component to rack interface.
d. The FIR shall comply with the keep-out zone for rack pivot mechanism as defined in SSP 41017 Part 1, paragraph 3.2.1.1.2.
e. The FIR shall be capable of rotating a minimum of 80 degrees about the pivot point for on-orbit installation, removal, and ISS maintenance functions.
f. The FIR and FIR equipment that have Portable Fire Extinguisher (PFE) access ports shall maintain positive margins of safety when exposed to the PFE discharge rate given in Figure 26.
g. The FIR shall use the rack and crew restraints identified in SSP 30257:004 (for example, the 14-in. fixed-length tether and the 71-in. adjustable-length tether) to secure the rack in these rotated positions for payload operations and maintenance.
h. The FIR shall not have a pressure relief device on the front of the rack.
i. The FIR shall be designed in accordance with the requirements specified in SSP 52005.
j. For frequencies below 0.01 Hz, the FIR shall limit unbalanced translational average impulse to generate less than 10 lb-s (44.8 N-s) within any 10 to 500 second period, along any ISS coordinate system vector.
k. Between 0.01 and 300 Hz, the inactive ARIS FIR shall limit vibration so that the limits of Figure 27 (Table X) are not exceeded using the force method, or the limits of Figure 28 (Table XI) are not exceeded using the acceleration method.
l. The FIR shall limit force applied to the ISS over any ten second period to an impulse of no greater than 10 lb-s (44.5 N-s). Non-rack payloads shall limit force applied to the ISS over any ten second period to an impulse of no greater than 2.5 lb-s (11.1 N-s).
m. The FIR shall limit their peak force applied to the ISS to less than 1000 lb (4448 N) for any duration. NOTE: Meeting the transient requirements of both l and m does not obviate the need to also meet the 100 second vibration requirement of k for vibration included in and following the transient disturbance.
n. FIR vibration induced by payloads shall not exceed the on-board to off-board vibration force limit of Figure 29 (Table XII) during microgravity periods, considering ARIS suspended rack structural dynamics and control system interaction, while ARIS is actively isolating.

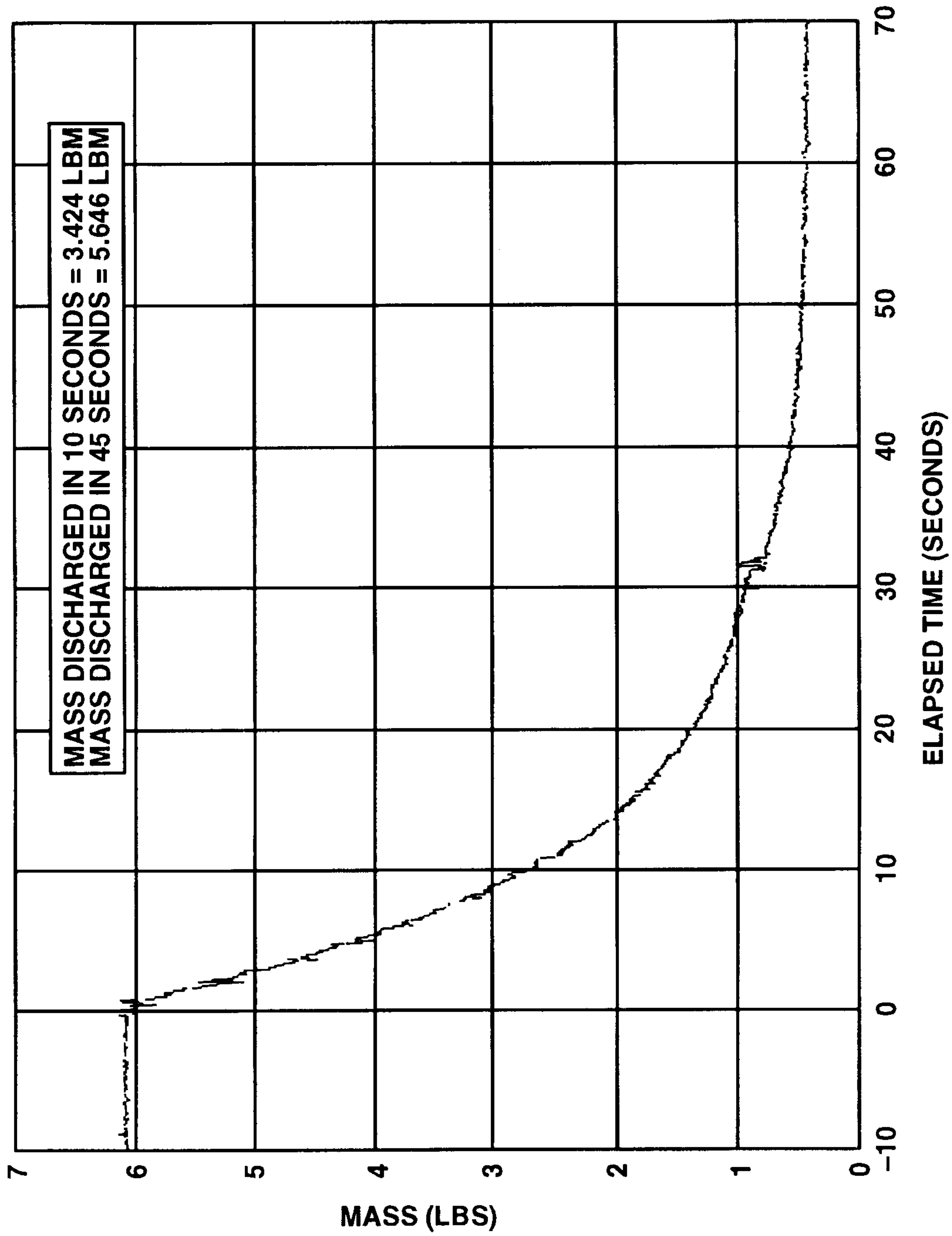


Figure 26. Manual fire suppression system performance characteristics at the rack interface

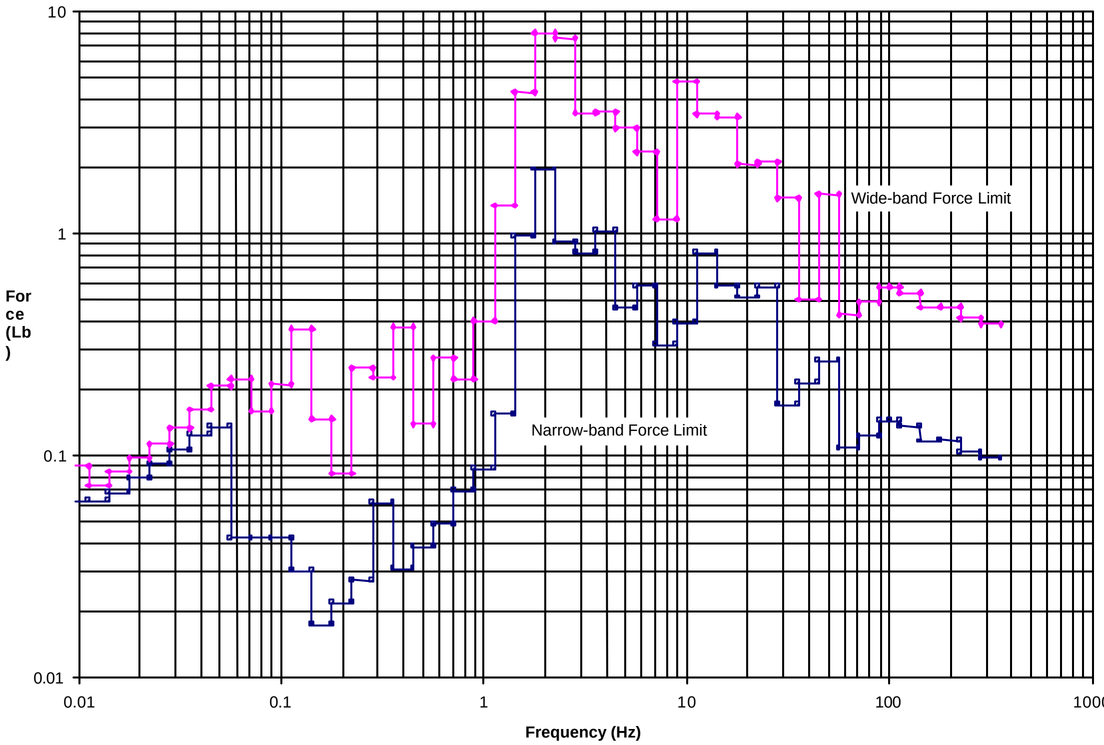


Figure 27. Allowable one-third octave interface forces for integrated racks and non-payloads, 0.5% damping factor

Freq (Hz)	NB lb f	WB Lb f
0.008913	0.06261	0.089635
0.01122	0.06261	0.089635
0.01122	0.06261	0.073218
0.01413	0.06261	0.073218
0.01413	0.068172	0.084667
0.01778	0.068172	0.084667
0.01778	0.079202	0.097495
0.02239	0.079202	0.097495
0.02239	0.091377	0.112968
0.02818	0.091377	0.112968
0.02818	0.105641	0.133067
0.03548	0.105641	0.133067
0.03548	0.123739	0.161094
0.04467	0.123739	0.161094
0.04467	0.134457	0.205508
0.05623	0.134457	0.205508
0.05623	0.042699	0.22137
0.07079	0.042699	0.22137
0.07079	0.042699	0.158917
0.08913	0.042699	0.158917
0.08913	0.042699	0.2093
0.1122	0.042699	0.2093
0.1122	0.030213	0.373089
0.1413	0.030213	0.373089
0.1413	0.017289	0.146008
0.1778	0.017289	0.146008
0.1778	0.021755	0.083429
0.2239	0.021755	0.083429
0.2239	0.027396	0.24715
0.2818	0.027396	0.24715
0.2818	0.061482	0.224779

Freq (Hz)	NB lb f	WB Lb f
0.3548	0.061482	0.224779
0.3548	0.030924	0.378806
0.4467	0.030924	0.378806
0.4467	0.038934	0.138909
0.5623	0.038934	0.138909
0.5623	0.04901	0.274588
0.7079	0.04901	0.274588
0.7079	0.06922	0.222568
0.8913	0.06922	0.222568
0.8913	0.087153	0.404688
1.122	0.087153	0.404688
1.122	0.154561	1.337042
1.413	0.154561	1.337042
1.413	0.976353	4.322593
1.778	0.976353	4.322593
1.778	1.953413	8.01995
2.239	1.953413	8.01995
2.239	0.915835	7.567684
2.818	0.915835	7.567684
2.818	0.818034	3.504552
3.548	0.818034	3.504552
3.548	1.029953	3.531682
4.467	1.029953	3.531682
4.467	0.460611	2.979207
5.623	0.460611	2.979207
5.623	0.579824	2.330438
7.079	0.579824	2.330438
7.079	0.315606	1.16448
8.913	0.315606	1.16448
8.913	0.39737	4.848007
11.22	0.39737	4.848007

Freq (Hz)	NB lb f	WB Lb f
11.22	0.817148	3.451307
14.13	0.817148	3.451307
14.13	0.579786	3.358266
17.78	0.579786	3.358266
17.78	0.516921	2.048448
22.39	0.516921	2.048448
22.39	0.57451	2.091627
28.18	0.57451	2.091627
28.18	0.168996	1.443748
35.48	0.168996	1.443748
35.48	0.212776	0.50643
44.67	0.212776	0.50643
44.67	0.267886	1.498072
56.23	0.267886	1.498072
56.231	0.10793	0.431721
70.79	0.10793	0.431721
70.791	0.122491	0.489965
89.13	0.122491	0.489965
89.131	0.143827	0.575309
100	0.143827	0.575309
112.2	0.143827	0.575309
112.2	0.135367	0.541469
141.3	0.135367	0.541469
141.3	0.115819	0.463274
177.8	0.115819	0.463274
177.8	0.116941	0.467763
223.9	0.116941	0.467763
223.9	0.104363	0.417452
281.8	0.104363	0.417452
281.8	0.097688	0.390751
354.8	0.097688	0.390751

Table X. Allowable integrated rack narrow-band envelope and wideband interface force values for ISPRs, 0.5% damping factor

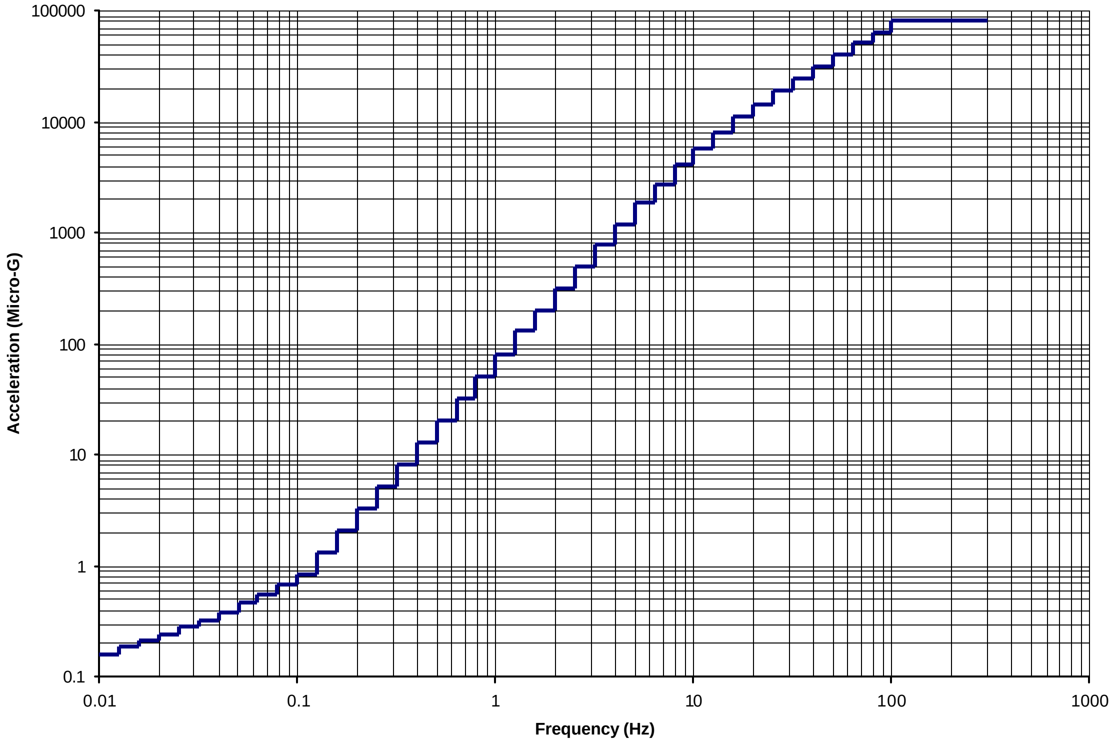


Figure 28. Non-ARIS-to ARIS acceleration limit alternative to force limits

Freq	Accel Limit (ug)	Freq	Accel Limit (ug)	Freq	Accel Limit (ug)
0.0089	0.159	0.226	5.18	5.74	2746
0.0112	0.159	0.285	5.18	7.23	2746
0.0112	0.185	0.285	8.19	7.23	4026
0.0141	0.185	0.359	8.19	9.11	4026
0.0141	0.213	0.359	12.97	9.11	5758
0.0178	0.213	0.452	12.97	11.48	5758
0.0178	0.244	0.452	20.53	11.48	8021
0.0224	0.244	0.570	20.53	14.47	8021
0.0224	0.281	0.570	32.49	14.47	10898
0.0283	0.281	0.718	32.49	18.23	10898
0.0283	0.325	0.718	51.42	18.23	14495
0.0356	0.325	0.904	51.42	22.96	14495
0.0356	0.383	0.904	81.33	22.96	18956
0.0449	0.383	1.139	81.33	28.93	18956
0.0449	0.458	1.139	128.51	28.93	24483
0.0565	0.458	1.435	128.51	36.45	24483
0.0565	0.556	1.435	202.73	36.45	31346
0.0712	0.556	1.808	202.73	45.93	31346
0.0712	0.682	1.808	318.99	45.93	39894
0.0897	0.682	2.278	318.99	57.87	39894
0.0897	0.843	2.278	499.90	57.87	50578
0.1130	0.843	2.871	499.90	72.91	50578
0.1130	1.322	2.871	778.69	72.91	63958
0.1424	1.322	3.617	778.69	91.86	63958
0.1424	2.079	3.617	1202.18	91.86	80751
0.1794	2.079	4.557	1202.18	100.00	80751
0.1794	3.280	4.557	1832.55	300.00	80751
0.2260	3.280	5.741	1832.55		

Table XI. Non-ARIS integrated rack to ARIS acceleration limit alternative to force limits

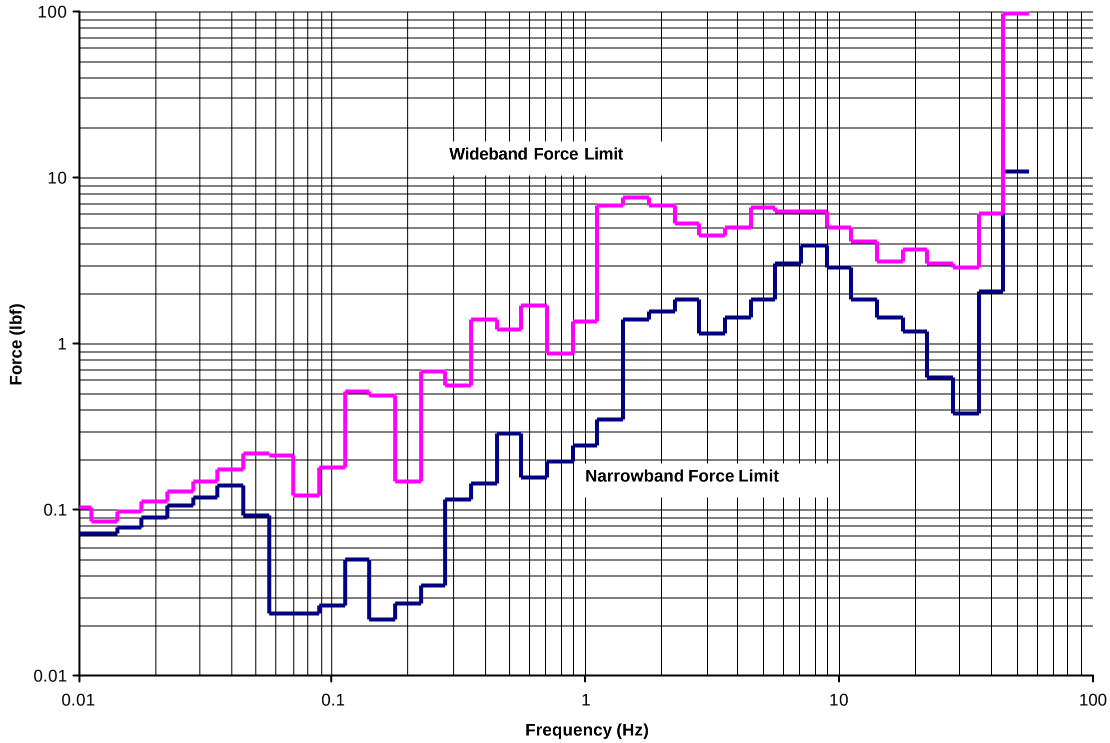


Figure 29. Allowable on-board force values for ARIS integrated payloads to meet off-board limits

Freq. (Hz.)	NBP Limit (lbf)	WB Limit (lbf)	Freq. (Hz.)	NBP Limit (lbf)	WB Limit (lbf)	Freq. (Hz.)	NBP Limit (lbf)	WB Limit (lbf)
0.0089	0.0722	0.1033	0.1778	0.0274	0.1466	3.5480	1.4337	5.0388
0.0112	0.0722	0.1033	0.2239	0.0274	0.1466	4.4670	1.4337	5.0388
0.0112	0.0722	0.0842	0.2239	0.0346	0.6819	4.4670	1.8234	6.6213
0.0141	0.0722	0.0842	0.2818	0.0346	0.6819	5.6230	1.8234	6.6213
0.0141	0.0785	0.0971	0.2818	0.1147	0.5577	5.6230	3.0271	6.2002
0.0178	0.0785	0.0971	0.3548	0.1147	0.5577	7.0790	3.0271	6.2002
0.0178	0.0910	0.1113	0.3548	0.1445	1.3967	7.0790	3.8832	6.2891
0.0224	0.0910	0.1113	0.4467	0.1445	1.3967	8.9130	3.8832	6.2891
0.0224	0.1046	0.1279	0.4467	0.2881	1.2088	8.9130	2.9020	5.0388
0.0282	0.1046	0.1279	0.5623	0.2881	1.2088	11.2200	2.9020	5.0388
0.0282	0.1201	0.1488	0.5623	0.1554	1.7174	11.2200	1.8602	4.0770
0.0355	0.1201	0.1488	0.7079	0.1554	1.7174	14.1300	1.8602	4.0770
0.0355	0.1392	0.1763	0.7079	0.1945	0.8709	14.1300	1.4350	3.0919
0.0447	0.1392	0.1763	0.8913	0.1945	0.8709	17.7800	1.4350	3.0919
0.0447	0.0926	0.2167	0.8913	0.2416	1.3743	17.7800	1.1754	3.7060
0.0562	0.0926	0.2167	1.1220	0.2416	1.3743	22.3900	1.1754	3.7060
0.0562	0.0240	0.2147	1.1220	0.3449	6.7131	22.3900	0.6179	3.0764
0.0708	0.0240	0.2147	1.4130	0.3449	6.7131	28.1800	0.6179	3.0764
0.0708	0.0240	0.1225	1.4130	1.3847	7.6318	28.1800	0.3821	2.9013
0.0891	0.0240	0.1225	1.7780	1.3847	7.6318	35.4800	0.3821	2.9013
0.0891	0.0269	0.1820	1.7780	1.5667	6.7883	35.4800	2.0342	6.0143
0.1122	0.0269	0.1820	2.2390	1.5667	6.7883	44.6700	2.0342	6.0143
0.1122	0.0502	0.5226	2.2390	1.8464	5.2891	44.6700	10.9057	96.2593
0.1413	0.0502	0.5226	2.8180	1.8464	5.2891	56.2300	10.9057	96.2593
0.1413	0.0218	0.4830	2.8180	1.1511	4.4228			
0.1778	0.0218	0.4830	3.5480	1.1511	4.4228			

Table XII. Allowable on-board force values for ARIS integrated payloads to meet off-board limits

3.2.6.4.3 Electrical requirements.

3.2.6.4.3.1 Steady-state voltage characteristics.

The FIR at Interface B shall operate and be compatible with the steady-state voltage limits of 116 to 126 Vdc.

3.2.6.4.3.2 Ripple voltage characteristics.

a. The FIR Electrical Power Consuming Equipment (EPCE) connected to Interface B shall operate and be compatible with the Electrical Power System (EPS) time domain ripple voltage and noise level of at least 2.5 Vrms within the frequency range of 30 Hz to 10k Hz.
b. The FIR EPCE connected to Interface B shall operate and be compatible with the EPS Ripple Voltage Spectrum as shown in Figure 30.
Note: This limit is 6 dB below the electromagnetic compatibility (EMC) CS-01, CS–02 requirement in SSP 30237 up to 30 MHz.

3.2.6.4.3.3 Transient voltages.

The FIR at Interface B shall operate and be compatible with the limits of magnitude and duration for the voltage transients at Interface B as shown in Figure 31.

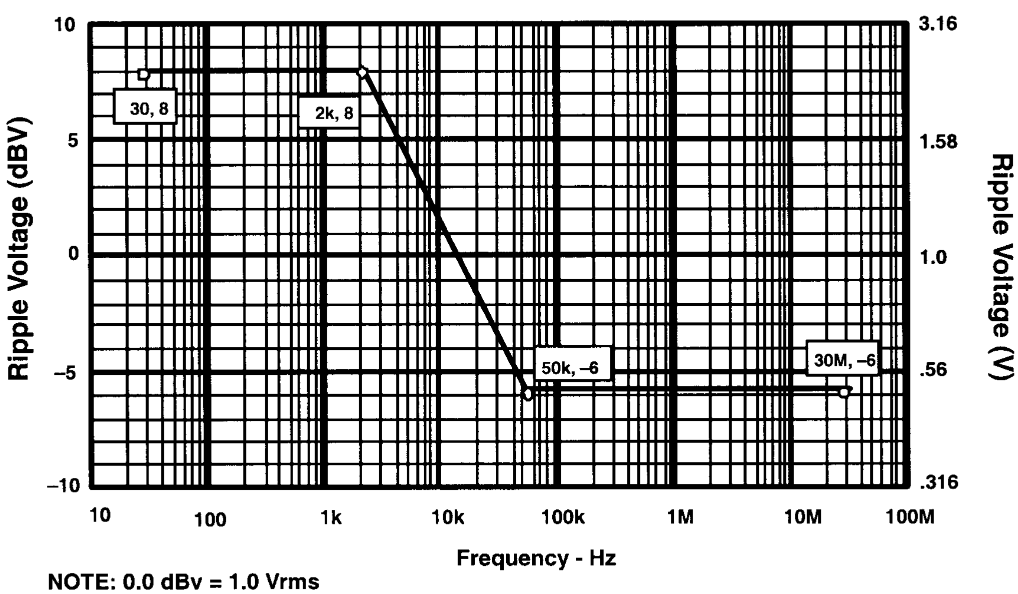


Figure 30. Maximum interfaces B and C ripple voltage spectrum

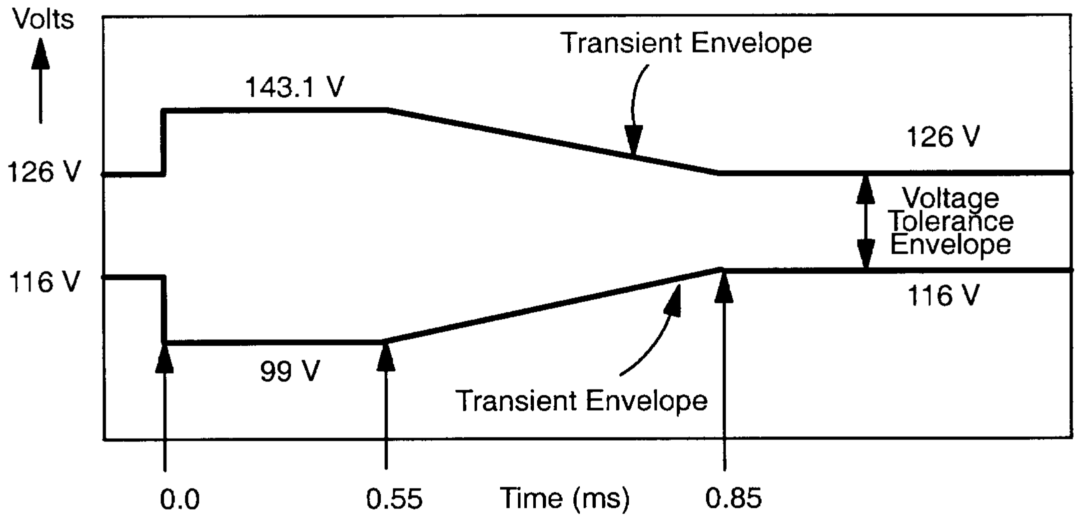


Figure 31. Interface B voltage transients

The envelope shown in this figure applies to the transient responses exclusive of any periodic ripple or noise components that may be present.

3.2.6.4.3.4 Fault clearing and protection.

The FIR EPCE connected to Interface B shall be safe and not suffer damage with the transient voltage conditions that are within the limits shown in Figure 32. Loads may be exposed to transient overvoltage conditions during operation of the power system's fault protection components.

3.2.6.4.3.5 Non-normal voltage range.

The FIR EPCE connected to Interface B shall not produce an unsafe condition or one that could result in damage to ISS equipment or payload hardware with non-normal voltage characteristics of a maximum overvoltage of + 165 Vdc for 10 s and undervoltage conditions of +102 Vdc for an indefinite period of time.

3.2.6.4.3.6 Power bus isolation.

a. The FIR shall provide a minimum of 1-MΩ isolation in parallel with not more than 0.03 µF of mutual capacitance within internal and external rack EPCE at all times such that no single failure shall cause the independent power buses to be electrically tied. (Mutual capacitance is defined as line-to-line capacitance, exclusive of the EMI input filter.).

b. FIR internal and external FIR shall not use diodes to electrically tie together independent ISS power bus high side or return lines. These requirements apply to both supply and return lines. ISS provides the capability to support simultaneous use of Main (J1) and Auxiliary (J2) power at each ISPR location (except MPLM). Constrained element level payload operations may occur from individual payload racks, which automatically switch to or require simultaneous use of auxiliary power.

3.2.6.4.3.7 Compatibility with soft start/stop remote power controller (RPC).

The FIR EPCE connected to the Interface B shall initialize with the soft start/stop performance characteristics when power is applied, sustained, and removed by control of remote power control switches as specified in Figure 33.

3.2.6.4.3.8 Surge current.

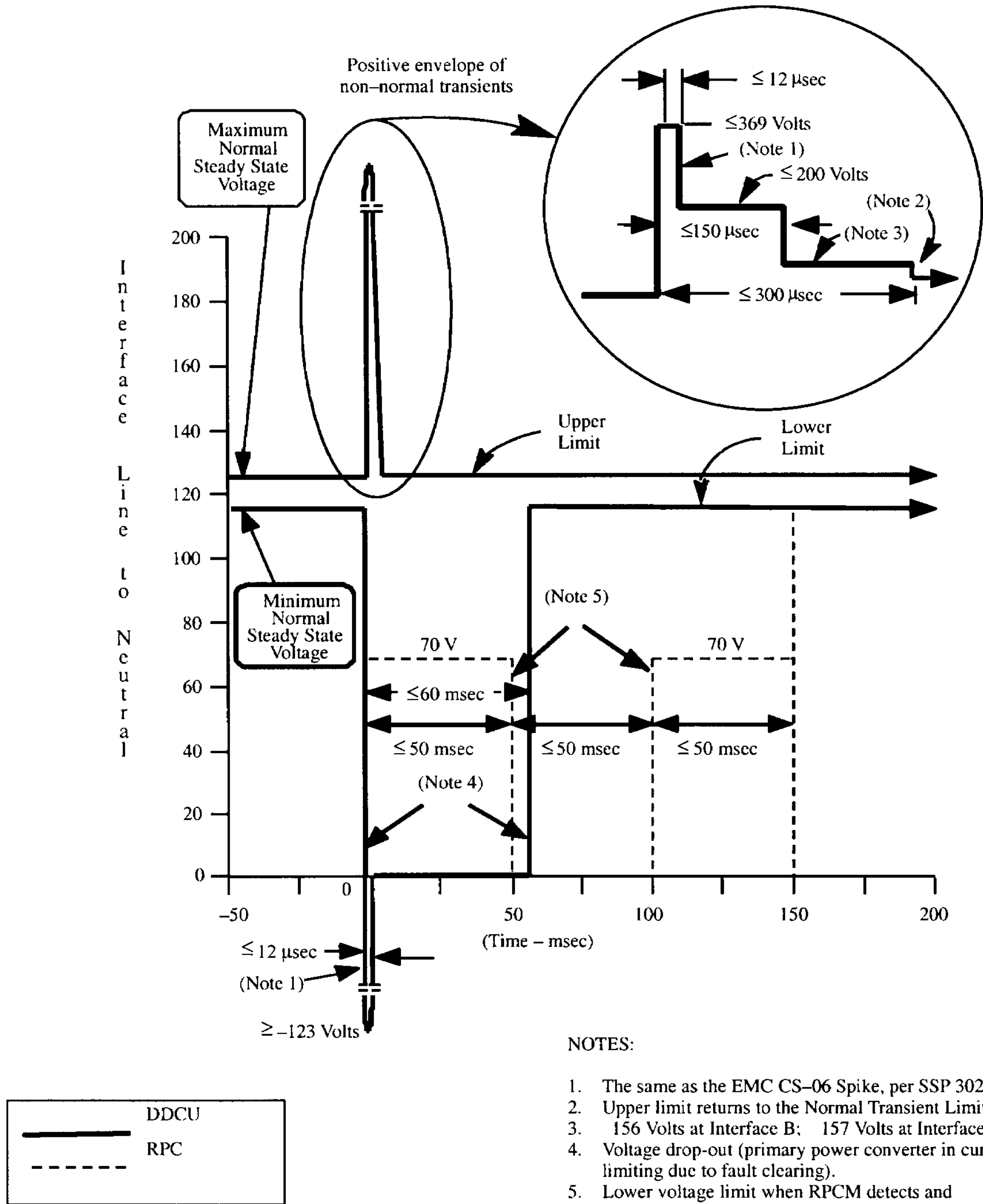
The FIR EPCE connected to Interface B electrical interface surge current at the power inputs shall not exceed the surge current values defined in Figure 34 and Figure 35 when powered from a voltage source with characteristics specified in SSP 57000, paragraphs 3.2.1 and 3.2.2.3, with the exception that the source impedance is considered to be 0.1 Ω. The duration of the surge current shall not exceed 10 ms. These requirements apply to all operating modes and changes including power-up and power-down.

3.2.6.4.3.9 Reverse energy/current.

The FIR electrical interface main input power and Auxiliary input power shall comply with the requirements defined in Table XIII for the reverse energy/current into the upstream power source. The FIR interface shall meet either the reverse energy or the reverse current requirement for all environmental conditions specified in this document when powered from a voltage source with characteristics specified in SSP 57000, paragraphs 3.2.1 and 3.2.2.3 with a source impedance of 0.1 Ω.

3.2.6.4.3.10 Current protection devices.

a. The FIR shall operate and be compatible with the characteristics in Figures 3.2.6–2, 3.2.6–3, and 3.2.6–4 as described in paragraph 3.2.6 located in SSP 57001.
b. Overcurrent protection shall be provided at all points in the system where power is distributed to lower level (wire size not protected by upstream circuit protection device) feeder and branch lines.
c. The FIR shall provide current limiting overcurrent protection for all internal loads (exclusive of overcurrent protection circuits and devices) drawing power from an Interface B power feed. For the purpose of this requirement, internal overcurrent protection circuits and devices are not considered to be loads.



NOTES:

1. The same as the EMC CS–06 Spike, per SSP 30237.
2. Upper limit returns to the Normal Transient Limit.
3. 156 Volts at Interface B; 157 Volts at Interface C.
4. Voltage drop-out (primary power converter in current limiting due to fault clearing).
5. Lower voltage limit when RPCM detects and responds to under voltage conditions.

Figure 32. Fault clearing and protection transient limits

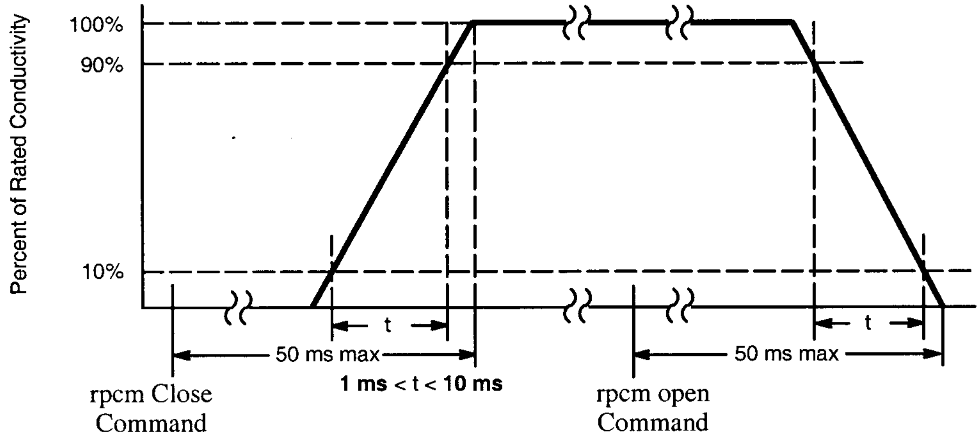


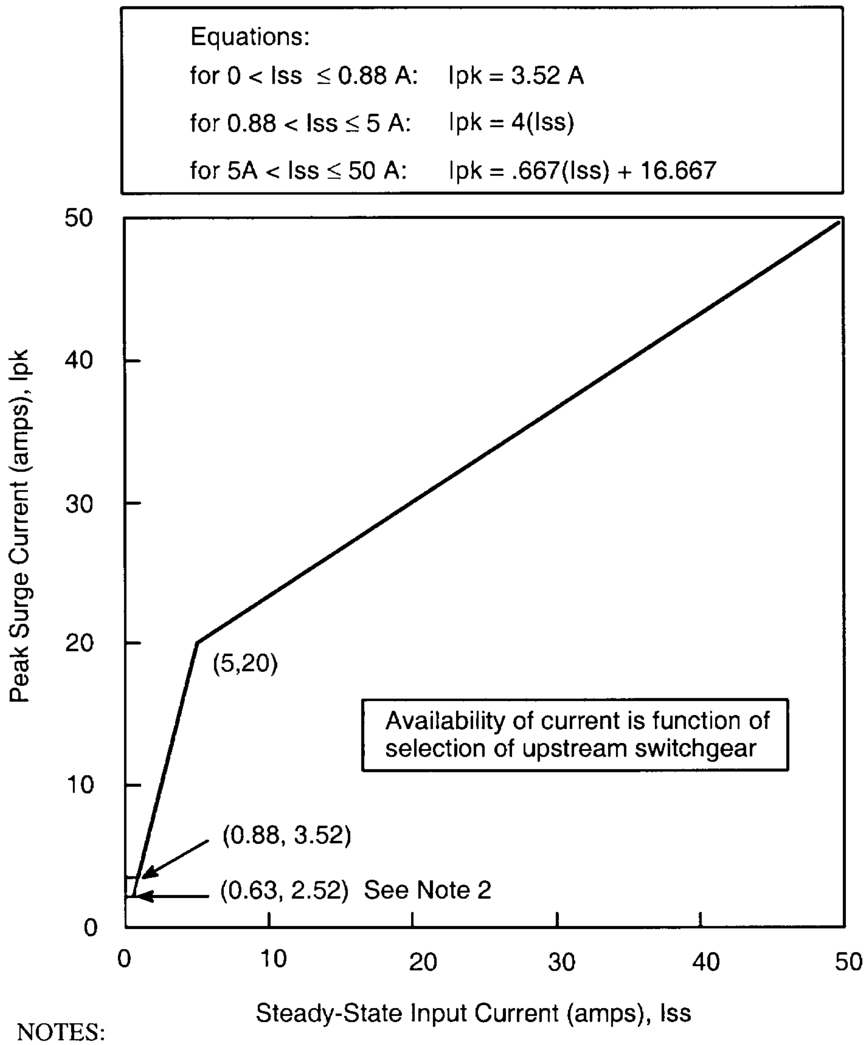
Figure 33. U.S. RPCM soft start/stop characteristics

3.2.6.4.3.11 FIR trip rating.

The payload power circuit protection device in the FIR connected to Interface B shall be designed to provide trip coordination, i.e., the downstream circuit protection device disconnects a shorted circuit or an overloaded circuit from the upstream power interface without tripping the upstream circuit protection device. The trip coordination is achieved either by shorter trip time or lower current limitation than the upstream protection devices defined in paragraph 3.2.6.4.3.10 a.

3.2.6.4.3.12 Interface B complex load impedances.

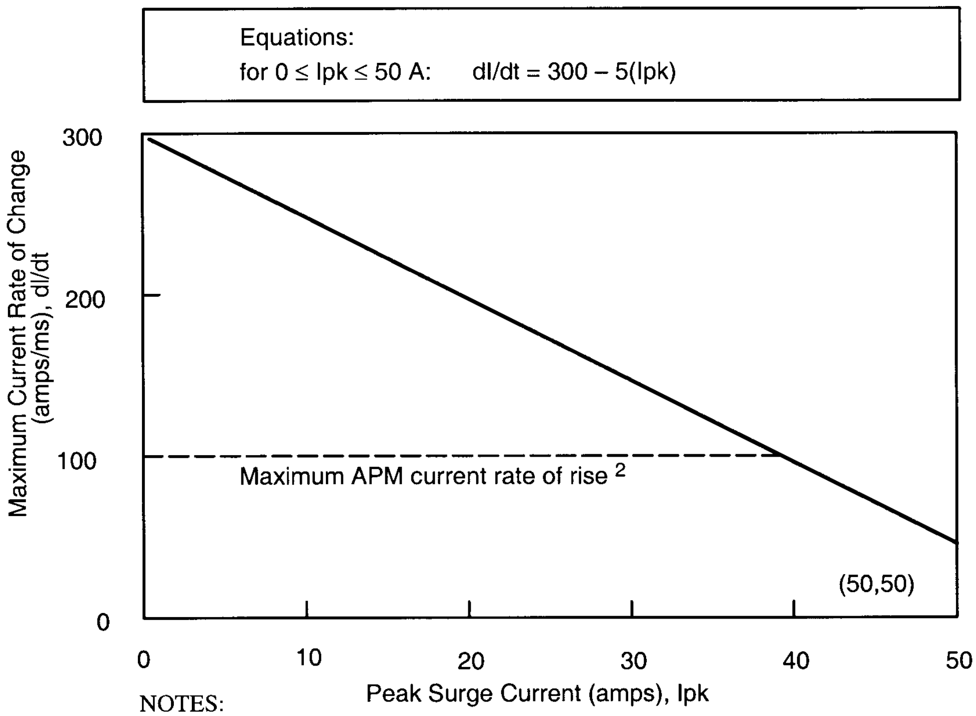
a. The load impedance presented by the FIR to the Main Interface B shall not exceed the bounds defined by Figure 36 and Figure 37 for input over the frequency range of 50 Hz to 100 kHz. The magnitude component of the FIR input impedance should not be less than the minimum defined in Figure 36 and Figure 37. At frequencies where the magnitude component of the FIR input impedance is less than the defined minimum, the phase component of the input impedance shall not exceed the bounds defined in Figure 36 and Figure 37.
b. The load impedance presented by the FIR to the 1.2 to 1.44 kW Interface B shall not exceed the bounds defined by Figure 38 for input over the frequency range of 50 Hz to 100 kHz. The magnitude component of the FIR input impedance should not be less than the minimum defined in Figure 38. At frequencies where the magnitude component of the FIR input impedance is less than the defined minimum, the phase component of the input impedance shall not exceed the bounds defined in Figure 38.



NOTES:

1. For transients less than 100 microseconds, refer to SSP 30237.
2. NASA Space Station equipment accommodated in JEM will have a maximum allowable peak surge current of 2.52 amps for equipment having a steady-state input no greater than 0.63 amps.

Figure 34. Peak surge current amplitude versus steady-state input current



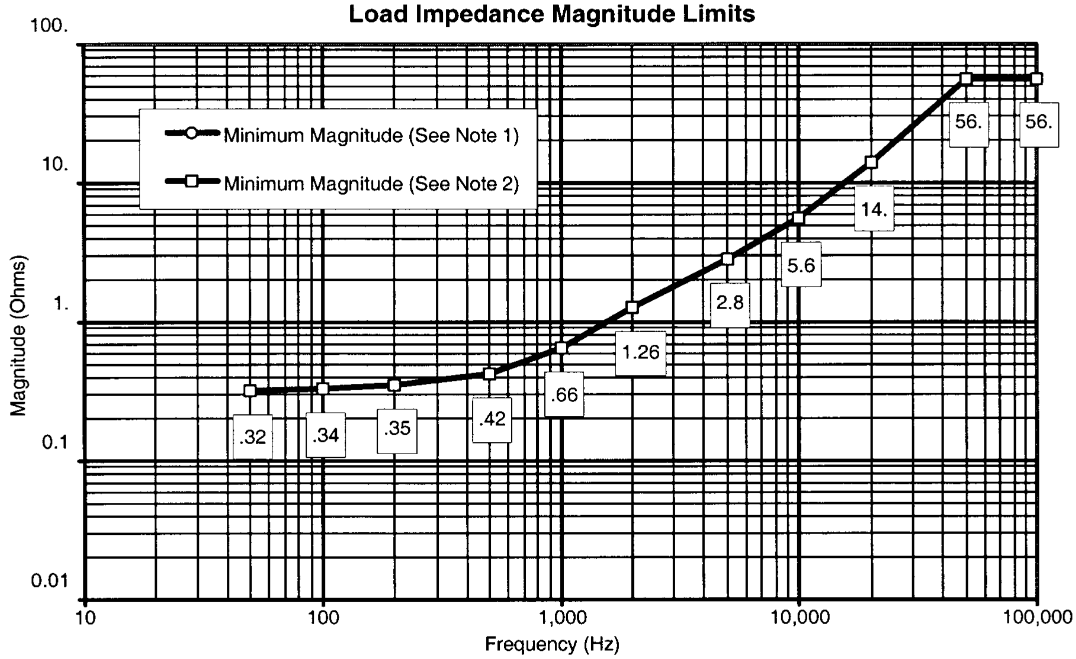
NOTES:

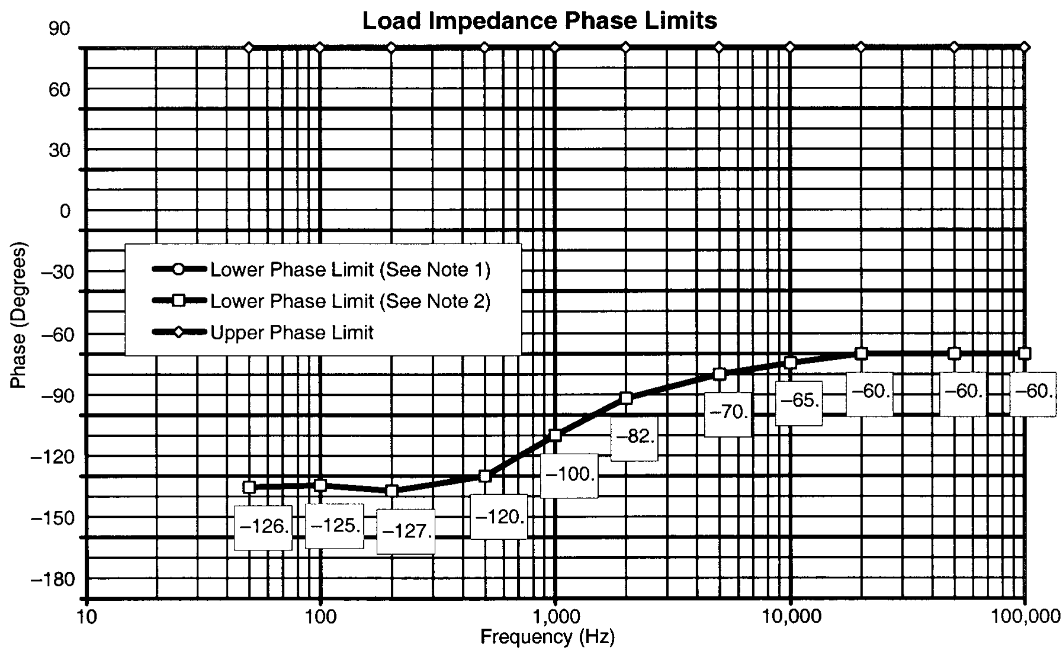
1. For transients less than 100 microseconds, refer to SSP 30237.
2. NASA Space Station and ISPR payload equipment accommodated in APM shall function correctly with a maximum current rate of rise of 100 amps/ms up to 40-amps peak surge current.

Figure 35. Maximum current rate of change versus peak surge current amplitude

Table XIII. Maximum reverse energy/current from downstream loads

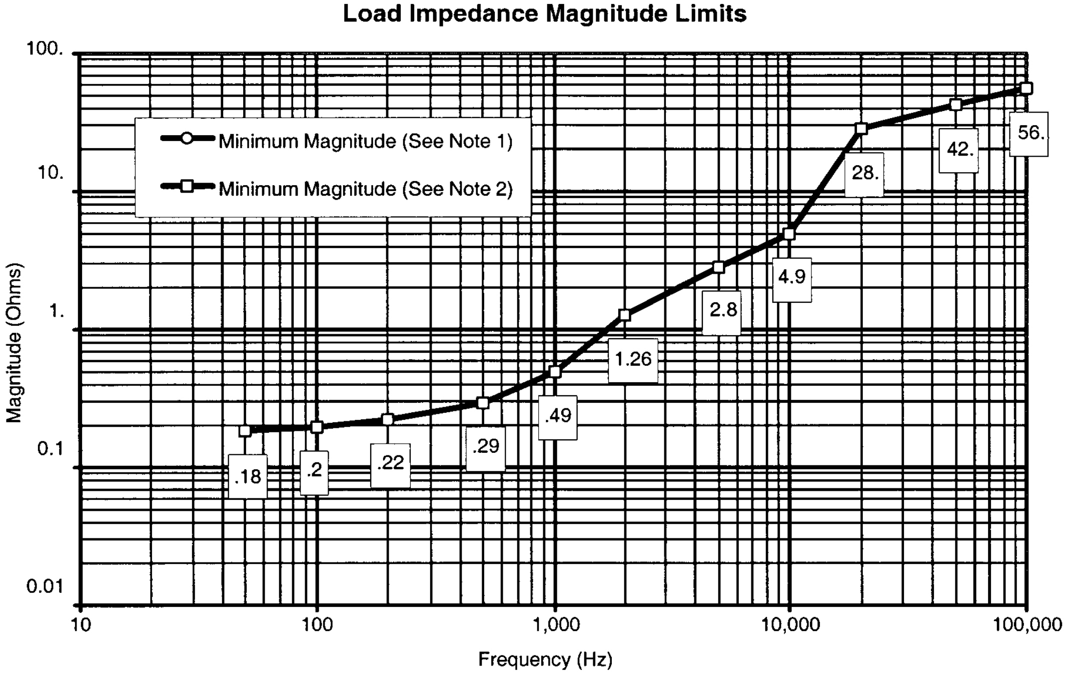
ISPR INTERFACE Power/RPCM type	MAXIMUM REVERSE ENERGY (Joules)	MAXIMUM REVERSE CURRENT (amps)		
		Pulse $t < 10\ \mu s$	Peak $t < 1$ ms	Steady State $t > 1$ s
3 kW / type VI	3.0	400	250	3
6 kW / type III	6.0	800	500	6
JEM	**(TBD #7)**	**(TBD #7)**	**(TBD #7)**	**(TBD #7)**
ESA	**(TBD #8)**	**(TBD #8)**	**(TBD #8)**	**(TBD #8)**
UOP Type I	1.5	400	250	2
UOP Type V	1.5	400	250	2
μs = microseconds ms = milliseconds s = second				

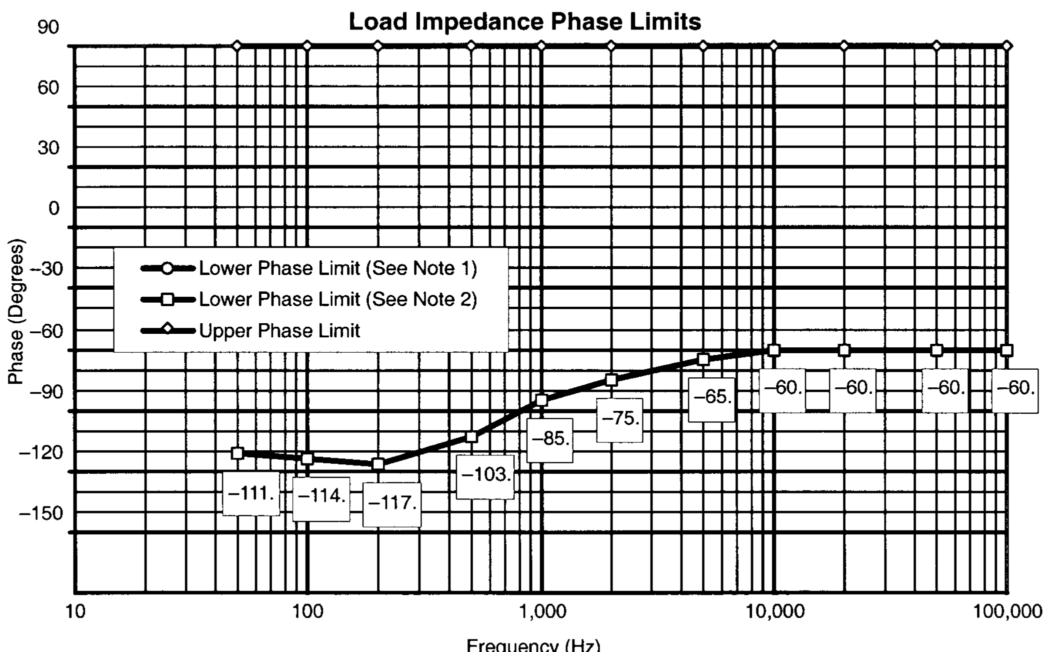




Notes:
1. Limit when total load on the Secondary Power Source is less than 400 watts.
2. Limit when total load on the Secondary Power Source is at least 400 watts.

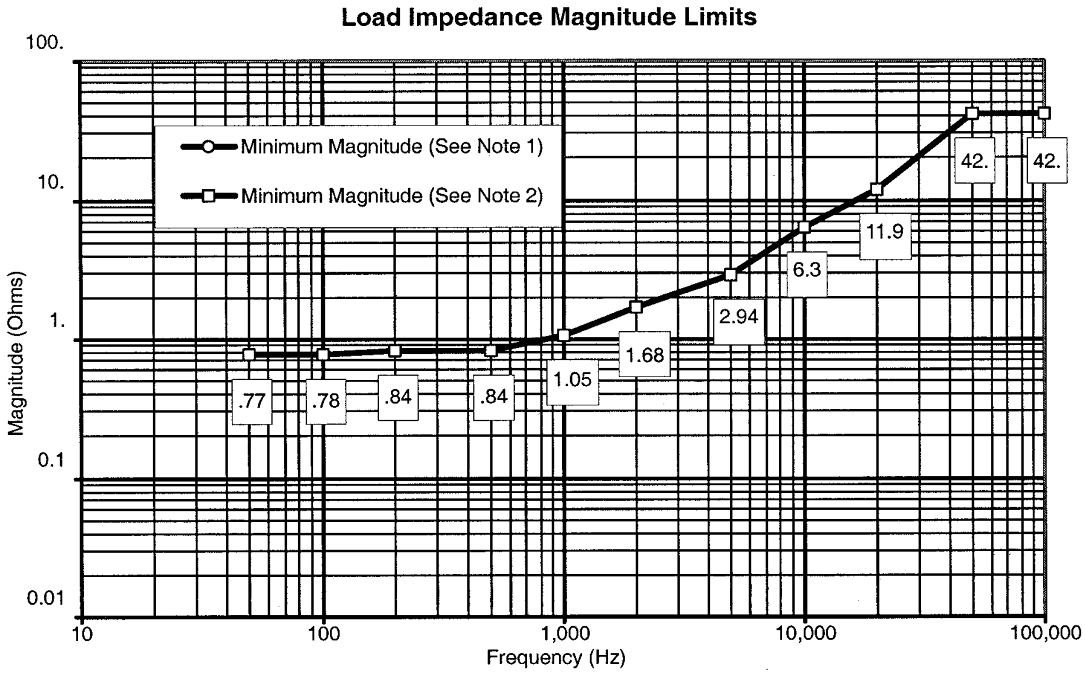
Figure 36. Interface B load impedance limits

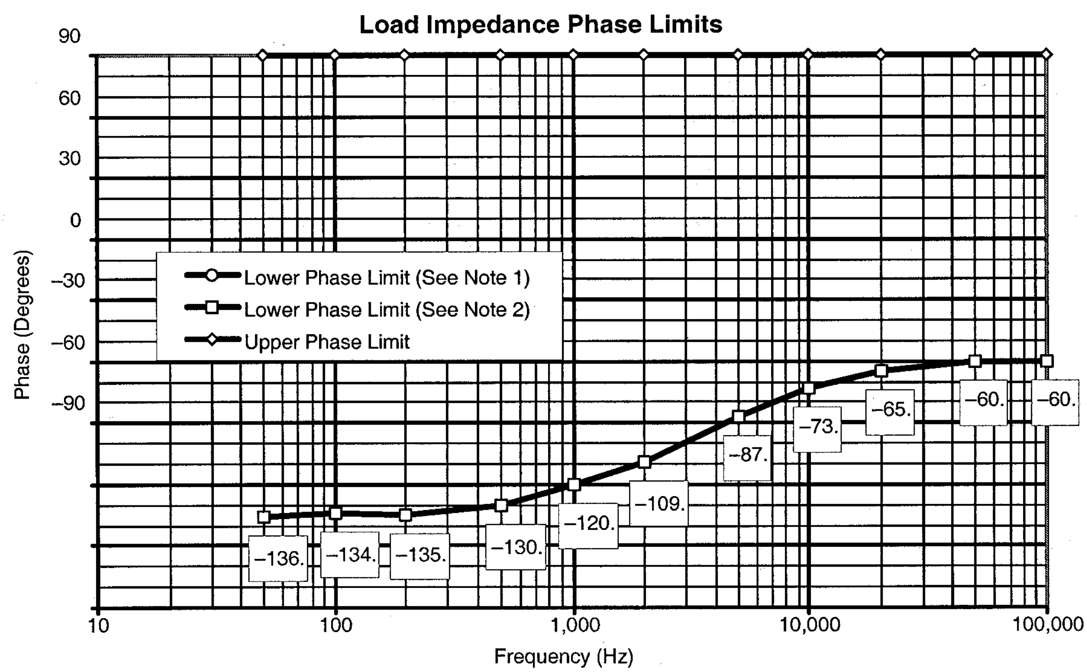




Notes:
1. Limit when total load on the Secondary Power Source is less than 400 watts.
2. Limit when total load on the Secondary Power Source is at least 400 watts.

Figure 37.6 kW Interface B Load impedance limits





Notes:
1. Limit when total load on the Secondary Power Source is less than 400 watts.
2. Limit when total load on the Secondary Power Source is at least 400 watts.

Figure 38.1.2 to 1.44 kW auxiliary inteface B load impedance limits

3.2.6.4.3.13 Large signal stability.

The FIR EPCE connected to Interface B shall maintain stability with the ISS EPS interface by damping a transient response to 10% of the maximum response amplitude within 1.0 ms, and remaining below 10% thereafter under the following conditions:

1. The rise time/fall time (between 10 and 90% of the amplitude) of the input voltage pulse is less than 10 μs.
2. The voltage pulse is to be varied from 100 to 150 μs in duration.

Note: Figure 39 is used to clarify the above requirement.

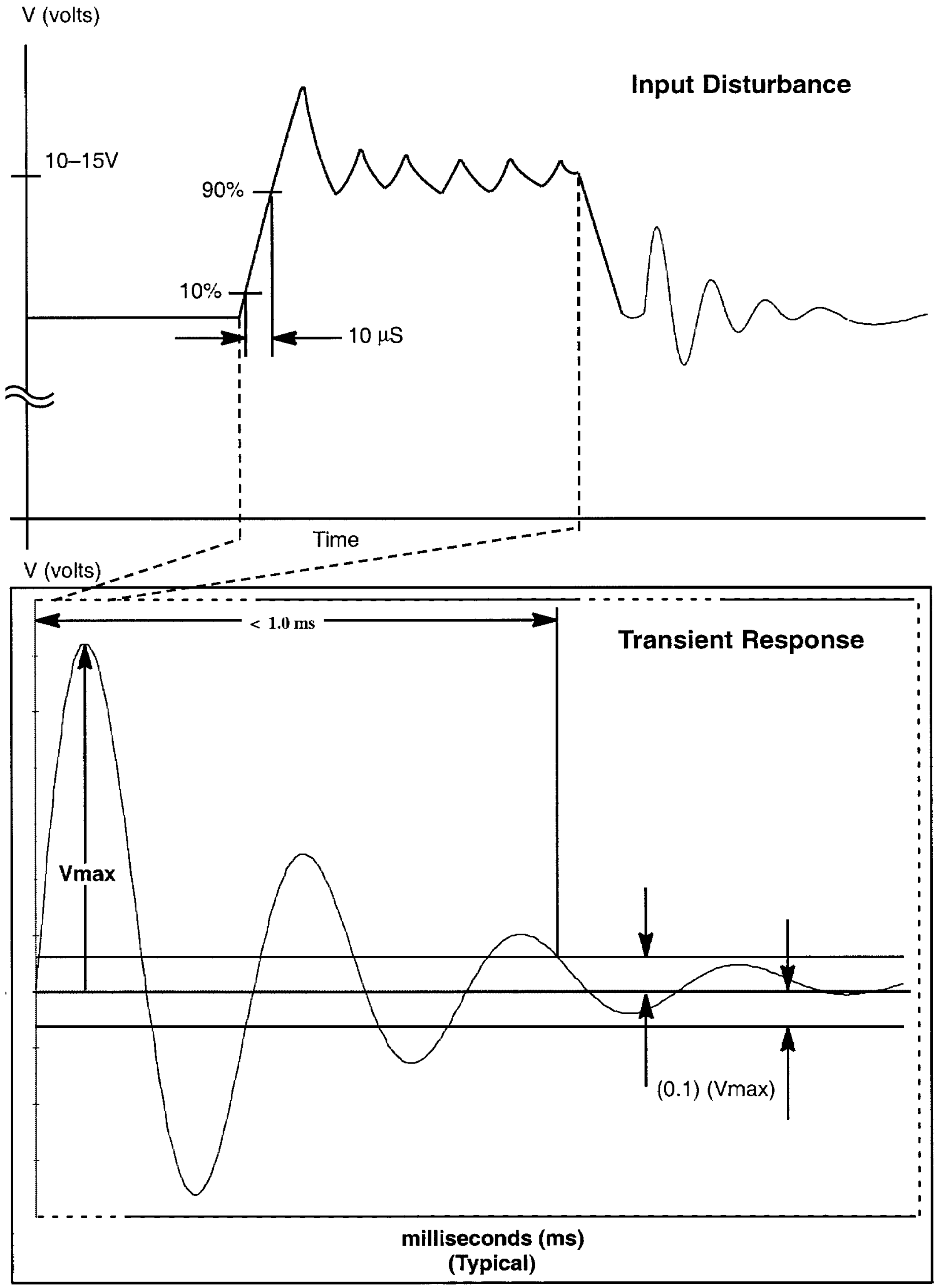


Figure 39. Pulse applied to the power input of the FIR

3.2.6.4.3.14 Maximum ripple voltage emissions.

The maximum ripple voltage induced on the power line by the FIR EPCE connected to Interface B shall be no greater than 0.5 V peak-to-peak.

3.2.6.4.3.15 Wire derating.

a. Derating criteria for EPCE at and downstream of the primary circuit protection device(s) in the FIR, as shown in Figure 40, shall be per NASA Technical Memo ™ 102179 as interpreted by NSTS 18798, TA-92-038.
b. The FIR shall use 4 gauge wire for main and auxiliary connections at the Utility Interface Panel (UIP).

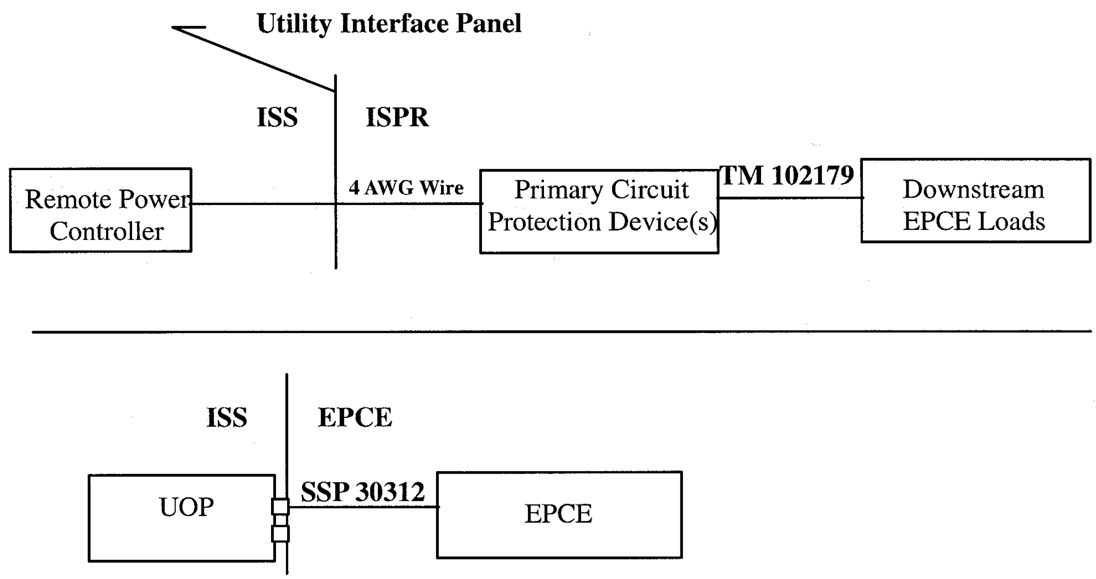


Figure 40. Wire derating requirements for FIR

3.2.6.4.3.16 Exclusive power feeds.

a. The FIR shall receive power only from the UIP dedicated to its rack location.
b. Cabling shall not occur between Interface C connected EPCE with Interface B; and/or Interface B connected EPCE with Interface C.

3.2.6.4.3.17 Loss of power.

The FIR shall fail safe in the event of a total or partial loss of power regardless of the availability of Auxiliary power in accordance with NSTS 1700.7, ISS Addendum.

3.2.6.4.3.18 Electromagnetic compatibility.

The FIR EPCE connected to Interface B shall meet the EMC requirements of SSP 30243, paragraphs 3.1 and 3.6.2.

3.2.6.4.3.18.1 Electrical grounding.

The FIR EPCE connected to Interface B shall meet all requirements specified in section 3 of SSP 30240.

3.2.6.4.3.18.2 Electrical bonding.

The FIR shall interface with the module bond strap per SSP 57001 Hardware ICD Template. Electrical bonding of EPCE connected to Interface B shall be in accordance with SSP 30245 and NSTS 1700.7 ISS Addendum, sections 213 and 220.

3.2.6.4.3.18.3 Cable/wire design and control requirements.

Cabling between FIR EPCE and Interface B shall meet all Cable and Wire Design requirements of SSP 30242.

3.2.6.4.3.18.4 Electromagnetic interference.

The FIR shall meet the requirements as specified in SSP 30237.

3.2.6.4.3.18.5 Electrostatic discharge.

The unpowered FIR and its components shall not be damaged by electrostatic discharge (ESD) equal to or less than 4,000 V to the case or any pin on external connectors. EPCE that may be damaged by ESD between 4,000 and 15,000 V shall have a label affixed to the case in a location clearly visible in the installed position.

3.2.6.4.3.18.6 Alternating current (ac) magnetic fields.

The generated ac magnetic fields, measured at a distance of 7 cm from the generating equipment, shall not exceed 140 dB above 1 pT for frequencies ranging from 30 Hz to 2 kHz, then falling 40 dB per decade to 50 kHz.

3.2.6.4.3.18.7 Direct current (dc) magnetic fields.

The generated dc magnetic fields shall not exceed 170 dB pT at a distance of 7 cm from the generating equipment. This applies to electromagnetic and permanent magnetic devices.

3.2.6.4.3.18.8 Corona.

Electrical and electronic subsystems, equipment, and systems shall be designed to preclude damaging or destructive corona in its operating environment. Guidance for meeting the corona requirement is found in MSFC–STD–531, High Voltage Design Criteria.

3.2.6.4.3.18.9 Lightning.

The FIR EPCE shall meet the lightning induced environment requirement in paragraph 3.2.8.1 of SSP 30243.

3.2.6.4.3.18.10 EMI susceptibility for safety-critical circuits.

Payload safety-critical circuits, as defined in SSP 30243, shall meet the margins defined in SSP 30243, paragraph 3.2.3.

3.2.7 Transportability.

The FIR shall be designed to be transportable within the United States without damage by truck or air via common commercial carrier when packaged as specified herein without requiring special accommodation to meet the transportation and handling limit load factors as specified in Table XIV.

Table XIV. Transportation and handling limit load factors

Mode	Load Occurrence	Fore/Aft g's	Lateral g's	Vertical g's
Air	I	±3.5	±2.0	+3.5/0.0
Truck/air ride trailer	I	±3.5	±2.0	+3.5/-1.5
Dolly(max velocity 8 km/hr (5 mph))	I	±1.0	±0.75	+2.0/-0.0
Forklifting	S	±1.0	±0.75	+2.0/-0.0
Hoisting	I	1.5 in direction of travel		

Notes:
S – Loads occur simultaneously in the three directions.
I – Loads occur independently in the three directions except for gravity.
Above load factors act at the center of gravity of the cargo.
Cargo weighing <136 kgs. Subject to additional loads cause by vibroacoustics for applicable transportation modes.
For ground transportation, the structure/carrier vehicle should be designed for the occurrence of a 15.4 m/s wind in combination with the load factors.
Cargo support structure will be designed, or carrier operation constrained, or both to insure that cargo loads will not exceed the design load.
Limit load factors listed in this table may be superseded by limit load factors derived for specific transportation mode/vehicle, transportation handling fixtures and handling equipment.
Vertical g's are positive in the direction of gravity (downward).

3.2.7.1 FIR launch and return.

The FIR in its launch configuration and stowed FIR hardware shall be designed to withstand a minimum of two shuttle launches and landings in the MPLM.

3.3 Design and construction.

3.3.1 Materials, processes, and parts.

3.3.1.1 FIR specific material requirements.

3.3.1.1.1 Materials – general.

Materials used in the FIR shall meet the requirements as specified in paragraphs 208.3 and 209 of NSTS 1700.7, NSTS 1700.7 ISS Addendum, and FCF-PLN-0036.

3.3.1.1.2 Internal Thermal Control System (ITCS) Fluids.

a. The FIR shall use ITCS fluids that meet the requirements specified in SSP 30573.
b. The FIR shall meet the fluid system cleanliness levels specified in SSP 30573.
c. The FIR shall use internal materials that are compatible according to MSFC-SPEC-250, Table III or that will not create a potential greater than 0.25 V with the ISS system internal materials due to a dissimilar metal couple.

3.3.1.1.3 Connectors.

Connectors used in the FIR, external to the assembly level, shall consist of MIL-C-38999, MIL-C-5015, MIL-C-81569, MIL-C-83733, or SSQ 21635 as specified in SSP 30423, Figure 4.1-8. See Appendix G.20 for exception to this requirement.

3.3.1.1.4 External cleanliness.

a. The FIR external surfaces, with applicable PI hardware, shall conform prior to launch to Visibly Clean – Sensitive (VC – S) cleanliness requirements, as specified in SN-C-0005.
b. The FIR external surfaces, with applicable PI hardware, shall meet the minimum acceptable cleanliness environment as measured by the U.S. Lab.

3.3.1.2 Toxic products and formulations.

The FIR shall meet the toxic product and formulation requirements as specified in FCF-PLN-0036.

3.3.1.3 Volatile organic compounds.

The FIR shall meet the volatile organic compound requirements as specified in FCF-PLN-0036.

3.3.1.4 Hazardous materials.

The FIR shall meet the hazardous material requirements as specified in FCF-PLN-0036.

3.3.1.5 Protective coatings.

The FIR shall meet the protective coating requirements as specified in FCF-PLN-0036.

3.3.2 Electromagnetic radiation.

3.3.2.1 Ionizing radiation.

Not applicable.

3.3.2.2 Nonionizing radiation.

Not applicable.

3.3.2.3 Operating environment.

Not applicable.

3.3.2.4 Generated environment.

Not applicable.

3.3.3 Nameplates and product marking.

3.3.3.1 Nameplates.

3.3.3.2 FIR identification and marking.

The FIR, all sub-rack elements (installed in the rack or separately), loose equipment, stowage trays, consumables, assemblies, crew accessible connectors and cables, switches, indicators, and controls shall be labeled as specified in SSP 57000 Appendix C.

3.3.3.2.1 FIR component identification and marking.

All FIR parts shall be legibly and permanently marked with a Part Identification Number (PIN) with the following exceptions:

a. Commercial-Off-the-Shelf (COTS) items marked with visible, permanent, and commercial identification.
b. Parts within a COTS assembly that are not subject to removal, replacement, or repair.

c. Parts within an assembly that are permanently installed and are not subject to removal, replacement, or repair.
d. Parts that cannot be physically marked or tagged due to lack of space or when marking would have a deleterious effect shall be temporarily tagged or packaged until the part is installed on the next higher assembly.

3.3.3.2.2 FIR lighting design.

a. FIR work surface specularity shall not exceed 20%. Paints listed in Table XV meet this requirement.
b. Lighting levels for tasks to be performed at FIR work sites shall be in accordance with Table XVI.
c. Medium FIR operational tasks shall utilize the ISS Portable Utility Light (PUL) specified in JSC 27199.
d. All text on surfaces intended to be read by the on-orbit crew shall be black lusterless, 37038 as specified in FED-STD-595, on off-white, semi-gloss, 27722 background as specified in FED-STD-595.
e. All aluminum surfaces susceptible to wear shall be clear or black hard coat anodized or equivalent. Exemptions from this requirement are in 3.3.3.2.2f.
f. FIR components shall be exempt from the lighting design requirement if the surfaces are color coded to meet other requirements as specified herein, such as interior component surfaces, COTS components, fluid system tubing, and surfaces required by science or safety to exhibit specific characteristics.

Table XV. Surface interior colors and paints

HARDWARE DESCRIPTION	COLOR	FINISH	PAINT SPECIFICATION PER FED–STD–595
Equipment Rack Utility Panel Recess	White	Semigloss	27925
Equipment Rack Utility Panel Text Characters	Black	Lusterless	37038
International Std. Payload Rack Primary Structure	Off-White	Semigloss	27722
ISPR Utility Panel Recess	White	Semigloss	27925
ISPR Utility Panel Recess Text Characters	Black	Lusterless	37038
Functional Unit Rack (Primary Structure)	Off-White	Semigloss	27722
Functional Unit Utility Panel Recess (as applicable)	White	Semigloss	27925
Functional Unit Utility Panel Recess Text Characters	Black	Lusterless	37038
Rack Front Aisle Extensions	Off-White	Semigloss	27722
Ceiling Rack Face Plates	Off-White	Semigloss	27722
Port Rack Face Plates	Off-White	Semigloss	27722
Starboard Rack Face Plates	Off-White	Semigloss	27722
Floor Rack Face Plates	Off-White	Semigloss	27722
Ceiling Rack Utility Panel Closeouts	Off-White	Semigloss	27722
Port Rack Utility Panel Closeouts	Off-White	Semigloss	27722
Starboard Rack Utility Panel Closeouts	Off-White	Semigloss	27722
Floor Rack Utility Panel Closeouts	Off-White	Semigloss	27722
Stowage Trays	Off-White	Semigloss	27722
Stowage Tray Handle Straps (any location)	Blue material	Semigloss	25102 or equiv.
Common Seat Track Interface	Clear (Anodized)	Semigloss	none
Glovebox (Aluminum or Plastic)	Medium Gray	Gloss	16329 or 16373
Glovebox (Aluminum)	White	Gloss	17925
Glovebox (Aluminum or Plastic)	Off-White	Gloss	17722
Glovebox (Aluminum)	Tan	Gloss	10475
EXPRESS Program Rack Utility Panels	Off–White	Gloss	17875

Table XVI.FIR required illumination levels

Type of Task	Required Lux (Foot-Candles)*
Medium payload operations (not performed in the aisle) (e.g., payload change-out and maintenance)	325 (30)
Fine payload operations (e.g., instrument repair)	1075 (100)
Medium glovebox operations (e.g., general operations, experiment set-up)	975 (90)
Fine glovebox operations (e.g., detailed operations, protein crystal growth, surgery/dissection, spot illumination)	1450 (135)

* As measured at the task site

3.3.3.2.3 Touch temperature warning labels.

Warning labels shall be provided at the surface site of any FIR component that exceeds a temperature of 49°C (120°F), including surfaces not normally exposed to the cabin, in accordance with the NASA IVA Touch Temperature Safety interpretation letter JSC, MA2-95-048.

3.3.3.2.4 Connector coding and labeling.

a. Both halves of FIR mating connectors shall display a code or identifier, which is unique to that connection.
b. The labels or codes on FIR connectors shall be located so they are visible when connected or disconnected.
c. Each FIR electrical connector pin shall be uniquely identifiable in each electrical plug and each electrical receptacle. At least every 10^{th} pin must be labeled. See Appendix G.21 for exception to this requirement.

3.3.3.3 Portable fire extinguisher (PFE) and fire detection indicator labeling.

a. The FIR shall label the Portable Fire Extinguisher (PFE) access port with a SDD32100397-002 “Fire Hole Decal” specified in JSC 27260.
b. The FIR shall label the Fire Detection Indicator Light Emitting Diode (LED) “SMOKE INDICATION” as specified in MSFC-STD-275, using 3.96 mm (0.156 in.) letters, style Futura Demibold, and color 37038 (Lusterless Black) per FED-STD-595.

3.3.3.4 Electrostatic discharge sensitive (ESD) parts labeling.

Labeling of EPCE susceptible to ESD up to 15,000 V shall be in accordance with MIL-STD-1686. These voltages are the result of charges that may be accumulated and discharged from ground personnel or crew members during equipment installation or removal.

3.3.4 Workmanship.

The FIR, with applicable PI hardware, shall conform to the workmanship standards in accordance with NHB 5300.4(1B).

3.3.5 Interchangeability.

All ORUs that have the same part number shall be functionally and dimensionally interchangeable.

3.3.6 Safety.

The FIR, with applicable hardware and software, shall meet all applicable requirements of NSTS 1700.7 ISS Addendum.

3.3.6.1 Fire Prevention.

The FIR shall meet the fire prevention requirements specified in NSTS 1700.7 ISS Addendum, paragraph 220.10 a.

3.3.6.1.1 Smoke detector.

a. The FIR, which contains potential fire sources and has forced air circulation, shall use a smoke detector that meets the requirements specified in D683-10007 and SSP 30262:013.
b. The FIR shall provide a smoke detector interface at the J43 connection with interface characteristics meeting the requirements specified in paragraph 3.3.6.1.1.1.

3.3.6.1.1.1 Maintenance switch, smoke detector, smoke indicator, and FIR fan interfaces.

a. The FIR power off command interface characteristics shall be in accordance with Table XVII.
b. The FIR power cut-off shall be implemented with a manually operated two-position lever lock switch.

3.3.6.1.1.2 Smoke detector analog interface characteristics.

The electrical characteristics (signal source) of the active driver interface shall be in accordance with Table XVIII.

PARAMETER	ENG. UNIT	ISPR
Type Transfer		Floating (Isolation resistance >1MΩ) dc coupled
I/F Resistance (closed)	Ω	< 20
I/F Resistance (open)	MΩ	> 1
Open Circuit Leakage Current	μA	0 to 100
Operating Current (closed)	mA	0.2 to 30
Minimum Open Circuit Voltage	V	20

Table XVII. Bi-level data characteristics (switch contact)

Table XVIII. Electrical characteristics envelope of analog signals

PARAMETER	ENG. UNIT	ANALOG SIGNALS
TYPE	N/A	Balanced
TRANSFER	N/A	DC Coupled
ANALOG VOLTAGE (line to line)	V	–5 to +5
RIPPLE AND NOISE	mV Peak (1)	±20
CAPACITY (Maximum)	nF	N/A
IMPEDANCE	Ohm	≤1K
OVERVOLTAGE PROTECTION (Min)	V	±15
FAULT VOLTAGE EMISSION (Max)	V	±15
FAULT CURRENT LIMIT. (Maximum)	mA	±10 (2)

Notes: (1) Measurement Bandwidth ≥ 50 MHz
(2) ISPR AAA= 30mA max

3.3.6.1.1.3 Discrete command built-in-test interface characteristics.

The discrete command built-in-test (BIT) interface characteristics (signal source) shall be in accordance with Table XIX.

Table XIX. Electrical characteristics of bit interface

PARAMETER	ENG. UNIT	SMOKE SENSOR
TYPE	N/A	Single-Ended
TRANSFER	N/A	DC Coupled
I/F VOLTAGE (TRUE) (line to line)	V	<1.5
OPERATING CURRENT ON (TRUE) (Max)	mA	2
RIPPLE AND NOISE	mV Peak (1)	±100
FAULT VOLTAGE EMISSION (Max)	V	±5
FAULT CURRENT EMISSION (Max)	mA	5

Notes: (1) Measurement Bandwidth ≥ 50 MHz
(2) If interface is active (on or true)

3.3.6.1.1.4 Smoke indicator electrical interfaces.

The smoke indicator electrical interface characteristics shall be in accordance with Table XX.

Table XX. Smoke indicator interface characteristics

PARAMETER	ENG. UNIT	SMOKE INDICATOR
TYPE	N/A	Floating
TRANSFER	N/A	DC Coupled
LOAD CURRENT (max)	mA	10
OVERVOLTAGE PROTECTION RANGE	V	±20
FAULT CURRENT EMISSION (max)	mA	24
IMPEDANCE (DC)	Ohm	>650

Note: At zero current rating (infinite load impedance)

3.3.6.1.1.5 Fan ventilation status electrical interfaces.

The FIR fan ventilation status electrical interface characteristics shall be in accordance with paragraph 3.3.6.1.1.2. The air is circulated through the smoke sensor in the FIR by a fan controlled and powered by the FIR.

3.3.6.1.1.6 Rack maintenance switch(rack power switch)/fire detection support interface connector.

a. FIR connector P43 mating requirements to the UIP Connector J43 shall be as specified in paragraph 3.1.5.1.
b. The FIR Maintenance Switch/FDS P43 Connector shall meet the pinout interfaces of the UIP J43 Connector as specified in SSP 57001, paragraph 3.3.6.
c. FIR Maintenance Switch/FDS P43 Connector shall meet the requirements of SSQ 21635 or equivalent.

3.3.6.1.2 Fire detection indicator.

a. The FIR shall provide a red Fire Detection Indicator LED in an easily visible location on the front of the rack that is powered by the ISS when the smoke detector senses smoke.
b. The FIR shall provide a fire detection indicator interface at the J43 connection with interface characteristics meeting the requirements specified in paragraph 3.3.6.1.1.1.

3.3.6.1.3 Forced air circulation indication.

The FIR shall provide a signal and data indicating whether or not the air flow specified in SSP 30262:013, paragraph 3.6.6 is being provided to the smoke detector when the smoke detector is in use.

3.3.6.1.4 Fire parameter monitoring in the FIR.

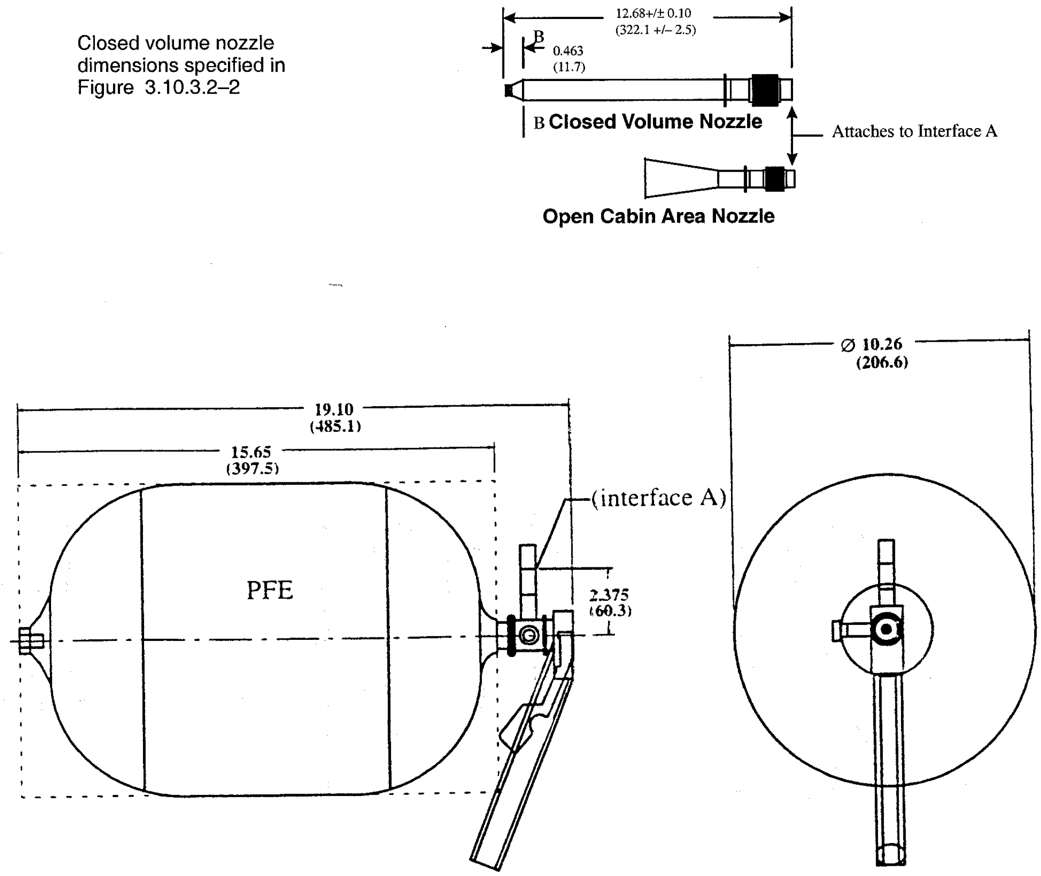
a. The FIR shall provide manual and automatic capabilities to terminate forced air circulation (if present) and power to the FIR.

   Note: Use of the Rack Maintenance Switch meets the manual requirement. For the FIR where the P/L Multiplexer-Demultiplexer (MDM) provides the monitoring function, the P/L MDM is capable of sending a command to the module Remote Power Controller (RPC) that will power off the FIR to meet the automatic requirement.

b. The FIR shall respond to an “out of bounds” condition by sending data to indicate the location and cause of the “out of bounds” condition to the payload MDM in the format specified in paragraph 3.4.1.1.5.4.

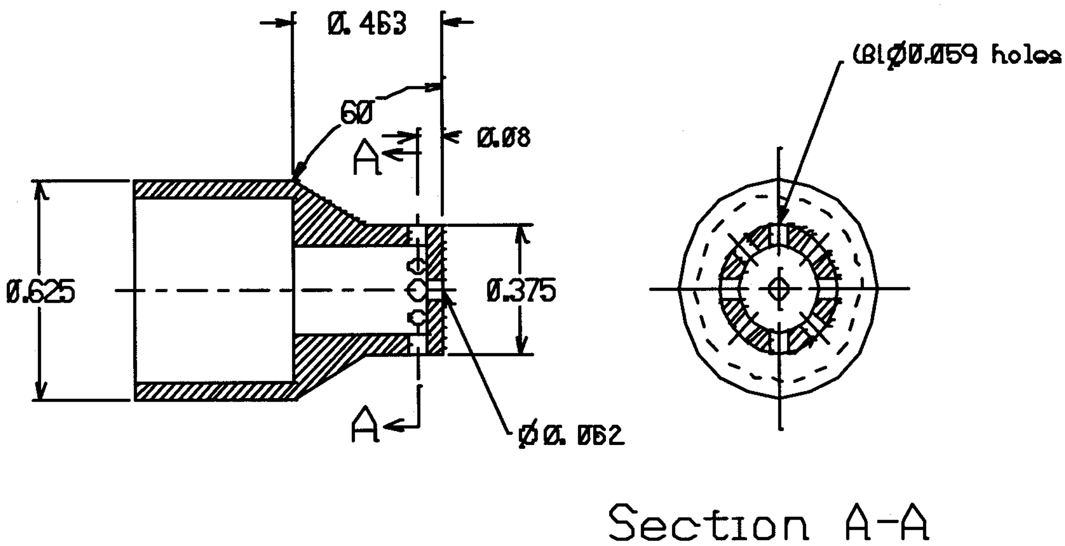
3.3.6.1.5 Fire suppression access port accessibility.

The FIR shall have a front face designed to accommodate the PFE nozzle and bottle specified in Figure 41 and Figure 42 so the PFE nozzle can interface to the PFE port.



Note: Measurements from PFE centerline to point B with the closed cabin Nozzle attached is approximately 14.59 inches (370.6 mm)

Figure 41. Manual fire suppression hardware envelope



Note: Linear dimensions are in inches, angular dimensions are in degrees.

Figure 42. Closed volume PFE nozzle

3.3.6.1.6 Fire suppressant distribution.

The internal layout of the FIR shall allow ISS PFE fire suppressant to be distributed to the entire volume that PFE access port serves, lowering the oxygen concentration to or below 10.5% by volume at any point within the enclosure within one minute.

3.3.6.2 FIR front surface temperature.

The FIR shall be designed such that the average front surface temperature is less than 37°C (98.6°F) and partial limit not to exceed 49° C (120°F).

3.3.6.3 Electrical hazards.

FIR electrical equipment shall incorporate the following controls as specified below:

a. If the exposure condition is below the threshold for shock (i.e., below maximum leakage current and voltage requirements as defined within this section), no controls are required. Non-patient equipment with internal voltages not exceeding 30 Vrms or dc nominal (32 Vrms or dc maximum) will contain potentials below the threshold for electrical shock.
b. If the exposure condition exceeds the threshold for shock, but is below the threshold of the let-go current profile (critical hazard) as defined in Table XXI, two

independent controls (e.g., a safety (green) wire, bonding, insulation, leakage current levels below maximum requirements) shall be provided such that no single failure, event, or environment can eliminate more than one control.

c. If the exposure condition exceeds both the threshold for shock and the threshold of the let-go current profile (catastrophic hazardous events) as defined in Table XXI, three independent controls shall be provided such that no combination of two failures, events, or environments can eliminate more than two controls.
d. If two dependent controls are provided, the physiological effect that a crew member experiences as a result of the combinations of the highest internal voltage applied to or generated within the equipment and the frequency and wave form associated with a worst case credible failure shall be below the threshold of the let-go current profile as defined in Table XXI.
e. If it cannot be demonstrated that the hazard meets the conditions of paragraph a, b, or c above, three independent hazard controls shall be provided such that no combination of two failures, events, or environments can eliminate more than two controls.

Table XXI.Let-go current profile threshold versus frequency

Frequency (Hertz)	Maximum Total Peak Current (AC + DC components combined) (milliamperes)
DC	40
15	8.5
2000	8.5
3000	13.5
4000	15.0
5000	16.5
6000	17.9
7000	19.4
8000	20.9
9000	22.5
10000	24.3
50000	24.3
(Based on 99.5 Percentile Rank of Adults)	

3.3.6.4 Connector mating.

a. The design of electrical connectors shall make it impossible to inadvertently reverse a connection or mate the wrong connectors if a hazardous condition can be created.
b. FIR and on-orbit support equipment, wire harnesses, and connectors shall be designed such that no blind connections or disconnections must be made during FIR installation, operation, removal, or maintenance on orbit unless the design includes scoop proof connectors or other protective features (NSTS 1700.7 ISS Addendum, paragraph 221).

c. FIR equipment, for which mismating or cross-connection may damage ISS-provided equipment, plugs, and receptacles (connectors), shall be selected and applied such that it cannot be mismatched or cross-connected in the intended system as well as adjacent systems. Although identification markings or labels are required, the use of identification alone is not sufficient to preclude mismating.
d. For all other FIR connections, combinations of identification, keying and clocking, and equipment test, and checkout procedures shall be employed at the payload's discretion to minimize equipment risk while maximizing on-orbit operability.

3.3.6.5 Mating/demating of powered connectors.

The FIR EPCE shall meet the electrical safety requirements as defined in NSTS 1700.7 ISS Addendum. Payloads shall comply with the requirements for mating/demating of powered connectors specified in NSTS 18798, MA2-97-093.

Note: The module can provide one verifiable upstream inhibit which removes voltage from the UIP and UOP connectors. The module design will provide the verification of the inhibit status at the time the inhibit is inserted.

3.3.6.6 Safety-critical circuit redundancy.

The FIR EPCE shall meet the electrical safety requirements as defined in NSTS 1700.7 ISS Addendum. The FIR EPCE connected to Interface B shall meet the safety-critical circuits redundancy requirements defined in NSTS 18798.

3.3.6.7 Rack maintenance switch (rack power switch).

The FIR shall provide a guarded, two-position, manually operated switch installed in a visible and accessible location on the front of the FIR that removes all power to the FIR.

3.3.6.8 Power switches/controls.

The following power switches/controls requirements apply to power to power interfaces with open circuit voltage exceeding 30 Vrms or dc nominal (32 Vrms or dc maximum).

a. Switches/controls performing on/off power functions for all power interfaces shall open (dead-face) all supply circuit conductors except the power return and the equipment grounding conductor while in the power-off position.
b. Power-off markings and/or indications shall be used only if all parts, with the exception of overcurrent devices and associated EMI filters, are disconnected from the supply circuit.
c. Standby, charging, or other descriptive nomenclature shall be used to indicate that the supply circuit is not completely disconnected for this power condition.

3.3.6.9 Ground fault circuit interrupters (GFCI)/portable equipment dc sourcing voltage.

a. A non-portable utility outlet with output voltages exceeding 30 Vrms or dc nominal (32 Vrms or dc maximum) intended to supply power to portable equipment shall include a GFCI, as an electrical hazard control, in the power path to the portable equipment.
b. GFCI trip current dc detection shall be independent of the portable equipment's safety (green) wire.
c. GFCI trip current ac detection shall be dependent on the portable equipment's safety (green) wire when the safety (green) wire is present.
d. Portable equipment that has internal voltages greater than 30 Vrms or dc nominal (32 Vrms or dc maximum) and has a credible fault path or return path to a crew member shall include GFCI protection for that credible path with trip point characteristics such that tripping will not exceed the currents specified in the profile shown in Table XXI.
e. GFCI will be designed to trip below the threshold of let-go based upon the 99.5 percentile rank of adults. Non-portable utility outlets supplying power to portable equipment shall include a GFCI with trip point characteristics such that tripping will not exceed the currents specified in the profile shown in Table XXI.
f. GFCIs shall remove power within 25 ms upon encountering the fault current.
g. GFCI shall provide an on-orbit method for testing trip current detection threshold at dc and at a frequency within the maximum human sensitivity range of 15 to 70 Hz.

3.3.6.10 Portable equipment/power cords.

a. Non-battery powered portable equipment shall incorporate a three-wire power cord.
b. Fault currents resulting from a single failure within a non-battery powered portable equipment that has internal voltage above 30 Vrms or dc nominal (32 Vrms or dc maximum) and has a credible fault path or return path to the crew member shall not exceed the total peak currents specified in Table XXI for fault current frequencies of 15 Hz and above.

3.3.6.11 Overload protection.

3.3.6.11.1 Device accessibility.

An overload protective device shall not be accessible without opening a door or cover, except that an operating handle or operating button of a circuit breaker, the cap of an extractor-type fuse holder, and similar parts may project outside the enclosure.

3.3.6.11.2 Extractor-type fuse holder.

The design of the extractor-type fuse holder shall be such that the fuse is extracted when the cap is removed.

3.3.6.11.3 Overload protection location.

Overload protection (fuses and circuit breakers) intended to be manually replaced or physically reset on-orbit shall be located where they can be seen and replaced or reset without removing other components.

3.3.6.11.4 Overload protection identification.

Each overload protector (fuse or circuit breaker) intended to be manually replaced or physically reset on-orbit shall be readily identified or keyed for its proper value.

3.3.6.11.5 Automatic restart protection.

Controls shall be employed that prevent automatic restarting after an overload-initiated shutdown.

3.3.6.12 Sharp edges and corners protection.

The FIR design shall protect crew members from sharp edges and corners during all crew operations in accordance with NSTS 1700.7 ISS Addendum, paragraph 222.1.

3.3.6.13 Holes.

Holes that are round or slotted in the range of 10.0 to 25.0 mm (0.4 to 1.0 in.) shall be covered.

3.3.6.14 Latches.

Latches that pivot, retract, or flex so that a gap of less than 35 mm (1.4 in.) exists shall be designed to prevent entrapment of a crew member's appendage.

3.3.6.15 Screw and bolts.

Threaded ends of screws and bolts accessible by the crew and extending more than 3.0 mm (0.12 in.) shall be capped to protect against sharp threads.

3.3.6.16 Securing pins.

Securing pins shall be designed to prevent their inadvertently backing out above the handhold surface.

3.3.6.17 Levers, cranks, hooks, and controls.

Levers, cranks, hooks, and controls shall not be located where they can pinch, snag, or cut the crew members or their clothing.

3.3.6.18 Burrs.

Exposed surfaces shall be free of burrs.

3.3.6.19 Locking wires.

a. Safety wires shall not be used on fasteners that must be unfastened for on-orbit removal or replacement.
b. All fracture-critical fasteners as defined in SSP 52005 (paragraph 5.6, Fastener Requirements, and Appendix B, Glossary of Terms) that must be unfastened for on-orbit removal or replacement shall be safety cabled or cotter pinned.

3.3.6.20 Audio devices (displays).

a. The design of audio devices (displays) and circuits shall protect against false alarms.
b. All audio device (displays) shall be equipped with circuit test devices or other means of operability testing.
c. An interlocked, manual disable shall be provided if there is any failure mode that can result in a sustained activation of an audio device (display).

3.3.6.21 Egress.

All FIR egress requirements shall be in accordance with 1700.7 ISS Addendum, paragraph 205.

3.3.6.22 Failure tolerance.

The FIR shall be single fault tolerant for the operation of a computer to identify failures to allow for active troubleshooting.

3.3.6.23 Failure propagation.

a. The FIR shall be designed such that a failure within an assembly will not induce any failure external to the failed assembly.
b. The FIR shall be designed such that a failure within the FIR will not induce a failure to any system or component external to the FIR.

3.3.6.24 Incorrect equipment installation.

The FIR assemblies and components that are replaceable on orbit shall contain physical provisions to preclude incorrect installation that may result in damage to equipment or hazardous conditions.

3.3.6.25 Chemical releases.

Chemical releases to the cabin air shall be in accordance with paragraphs 209.1 a. and 209.1 b. in NSTS 1700.7 ISS Addendum.

3.3.6.26 Single event effect (SEE) ionizing radiation.

The FIR, with applicable PI hardware, shall be designed not to produce an unsafe condition or one that could cause damage to equipment external to the FIR as a result of exposure to SEE ionizing radiation assuming exposure levels specified in SSP 30512, paragraph 3.2.1, with a shielding thickness of 25.4 mm (1000 mils).

3.3.6.27 Potential hazardous conditions.

a. The FIR shall determine if any out-of-tolerance conditions will lead to a hazardous condition and take steps necessary to prevent the hazardous condition.
b. Any autonomous reconfigurations performed to prevent a hazardous condition from occurring shall be capable of being overridden.

3.3.6.28 Withstand external environment.

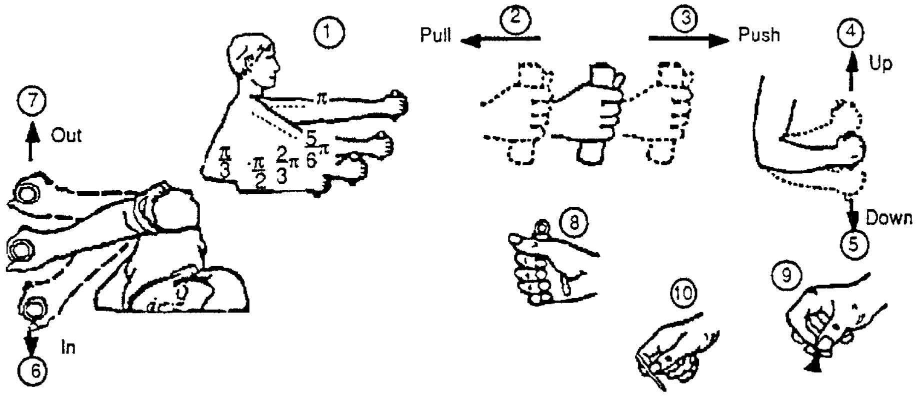
The FIR shall be designed to withstand changes in its external environment to prevent hazardous conditions within the FIR from occurring internal or external to the FIR.

3.3.7 Human performance/human engineering.

3.3.7.1 Strength requirements.

Forces and torques required to remove, replace, operate, control, and maintain FIR hardware and equipment on orbit shall be equal to or less than the strength values given below.

a. For operation and control of FIR hardware equipment:
    1. Grip Strength – To remove, replace, and operate FIR hardware, grip strength required shall be less than 254 N (57 lbf).
    2. Linear Forces – Linear forces required to operate or control FIR hardware or equipment shall be less than the strength values for the 5^{th} percentile female, defined as 50% of the strength values shown in Figure 43 and 60% of the strength values shown in Figure 44.
    3. Torques – Torques required to operate or control FIR hardware or equipment shall be less than the strength values for the 5^{th} percentile female, defined as 60% of the calculated 5^{th} percentile male capability shown in Figure 45.
b. Forces required for maintenance of FIR hardware and equipment shall be less than the 5^{th} percentile male strength values shown in Figure 43, Figure 44, Figure 45, Figure 46, Figure 47, and Figure 48.



Arm strength (N)												
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
Degree of elbow flexion (rad)	Pull		Push		Up		Down		In		Out	
	L**	R**	L	R	L	R	L	R	L	R	L	R
π	222	231	187	222	40	62	58	76	58	89	36	62
5/6 π	187	249	133	187	67	80	80	89	67	89	36	67
2/3 π	151	187	116	160	76	107	93	116	89	98	45	67
1/2 π	142	165	98	160	76	89	93	116	71	80	45	71
1/3 π	116	107	96	151	67	89	80	89	76	89	53	76

Hand and thumb-finger strength (N)				
	(8)		(9)	(10)
	Hand grip		Thumb-finger grip (Palmer)	Thumb-finger grip (tips)
	L	R		
Momentary hold	250	260	60	60
Sustained hold	145	155	35	35

* Elbow angle shown in radians
** L = Left; R = Right

Arm strength (lb)												
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
Degree of elbow flexion (deg)	Pull		Push		Up		Down		In		Out	
	L	R*	L	R	L	R	L	R	L	R	L	R
180	50	52	42	50	9	14	13	17	13	20	8	14
150	42	56	30	42	15	18	18	20	15	20	8	15
120	34	42	26	36	17	24	21	26	20	22	10	15
90	32	37	22	36	17	20	21	26	16	18	10	16
60	26	24	22	34	15	20	18	20	17	20	12	17

Hand, and thumb-finger strength (lb)				
	(8)		(9)	(10)
	Hand grip		Thumb-finger grip (Palmer)	Thumb-finger grip (tips)
	L	R		
Momentary hold	56	59	13	13
Sustained hold	33	35	8	8

* Left; R = Right

Figure 43. Arm, hand, and thumb/finger strength (5th percentile male data)

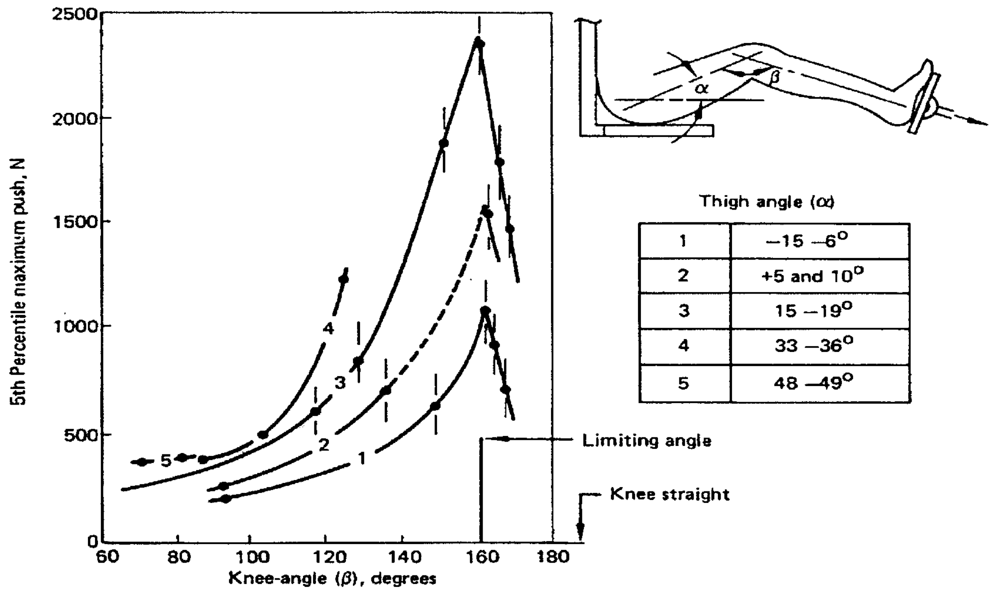


Figure 44. Leg strength at various knee and thigh angles (5th percentile male data)

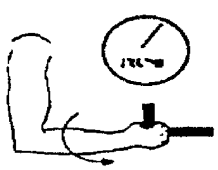
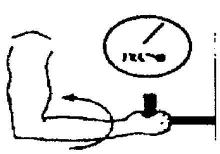
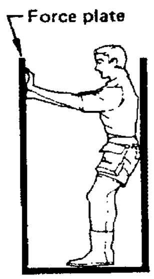
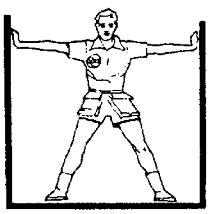
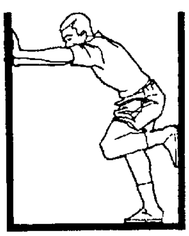
		Unpressurized suit, bare handed	
		Mean	SD
	Maximum torque: Suppination, Nm (lb-in.)	13.73 (121.5)	3.41 (30.1)
	Maximum torque: Pronation, Nm (lb-in.)	17.39 (153.9)	5.08 (45.0)

Figure 45. Torque strength

	Force-plate (1) height	Distances (2)	Force, N (lbf) Means	Force, N (lbf) SD
	100 percent of shoulder height		Both hands	
		50	583 (131)	142 (32)
		60	667 (150)	160 (36)
		70	983 (221)	271 (61)
		80	1285 (289)	400 (90)
		90	979 (220)	302 (68)
		100	645 (145)	254 (57)
			Preferred hand	
		50	262 (59)	67 (15)
		60	298 (67)	71 (16)
		70	360 (81)	98 (22)
		80	520 (117)	142 (32)
		90	494 (111)	169 (38)
		100	427 (96)	173 (39)
		Percent of thumb-tip reach *		
	100 percent of shoulder height	50	369 (83)	138 (31)
		60	347 (78)	125 (28)
		70	520 (117)	165 (37)
		80	707 (159)	191 (32)
		90	325 (73)	133 (30)
		Percent of span **		
	Force-plate (1) height	**Distances (2)**	**Force, N (lbf) Means**	**Force, N (lbf) SD**
	50	100	774 (174)	214 (48)
	50	120	778 (175)	165 (37)
	70	120	818 (184)	138 (31)
	Percent of shoulder height		1-g applicable data	

NOTES:

(1) Height of the center of the force plate - 200 mm (8 in) high by 254 mm (10 in) long - upon which force is applied.

(2) Horizontal distance between the vertical surface of the force plate and the opposing vertical surface (wall or footrest, respectively) against which the subject brace themselves.

() Thumb-tip reach - distance from backrest to tip of subject's thumb as thumb and fingertips are pressed together.

() Span - the maximal distance between a person's fingertips as he extends his arms and hands to each side.

(3) 1-g data.

Figure 46. Maximal static push forces

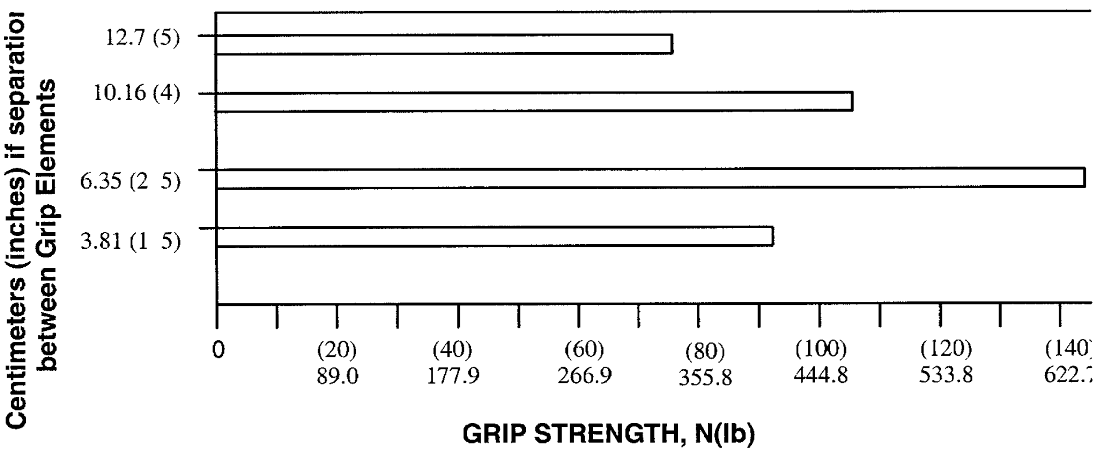


Figure 47. Male grip strength as a function of the separation between grip elements

3.3.7.2 Adequate crew clearance.

The FIR shall provide clearance for the crew to perform installation, operations, and maintenance tasks, including clearance for hand access, tools, and equipment used in these tasks.

3.3.7.3 Accessibility.

a. FIR hardware shall be geometrically arranged to provide physical and visual access for all FIR installation, operations, and maintenance tasks.
b. IVA clearances for finger access shall be provided as given in Figure 48.

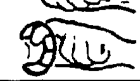
Minimal finger-access to first joint			
Push button access:	Bare hand: Thermal gloved hand:	32 mm dia (1.26 in) 38 mm dia (1.5 in)	
Two finger twist access:	Bare hand: Thermal gloved hand:	object plus 50 mm (1.97 in) object plus 65 mm (2.56 in)	

Figure 48. Minimum sizes for access openings for fingers

3.3.7.4 Full size range accommodation.

All FIR work stations and hardware having crew nominal operations and planned maintenance shall be sized to meet the functional reach limits for the 5th percentile

Japanese female and yet shall not constrict or confine the body envelope for the 95th percentile American male as specified in SSP 50005, section 3.

3.3.7.5 Housekeeping closures and covers.

Closures or covers shall be provided for any area of the payload that is not designed for routine cleaning.

3.3.7.6 Built-in housekeeping control.

a. FIR containers of liquids or particulate matter shall have built-in equipment/methods for control of vaporization, material overflow, or spills.
b. The capture elements, including grids, screens, or filter surfaces shall be accessible for replacement or cleaning without dispersion of the trapped materials.

3.3.7.7 One-handed operation.

Cleaning equipment and supplies shall be designed for one-handed operation or use.

3.3.7.8 Acoustic Requirements.

3.3.7.8.1 Continuous noise limits.

The Continuous Noise Source (see Glossary of Terms) for the FIR (including any supporting adjunct active portable equipment operated outside the FIR that is within or interfacing with the crew habitable volume) whose sub-rack equipment will be changed out on-orbit shall not, except in those cases when the rack meets the Intermittent Noise Source requirements specified in SSP 57000, paragraph 3.12.3.3.2, exceed the limits specified in Table XXII for all octave bands (NC-40 equivalent) when the equipment is operating in the loudest expected configuration and mode of operation that can occur on orbit under nominal crew, or hardware operation cicumstances, during FIR setup operations, or during nominal operations where doors/panels are opened or removed.

Note: These acoustic requirements do not apply during failure or maintenance operations.

3.3.7.8.2 Intermittent noise limits.

The FIR (including any supporting adjunct active portable equipment operated outside the FIR that is within or interfacing with the crew habitable volume) Intermittent Noise Source (See Glossary of Terms) shall not exceed the Total Rack A-weighted SPL Limits during the Maximum Rack Noise Duration as specified in Table XXIII when the equipment is operating in the loudest expected configuration and mode of operation that can occur on orbit under any planned operations.

Note: These acoustic requirements do not apply during failure or maintenance operations.

Table XXII. Continuous noise limits

Rack Noise Limits Measured At 0.6 Meters Distance From The Test Article	
Frequency Band Hz	Integrated Rack Sound Pressure Level (SPL)
63	64
125	56
250	50
500	45
1000	41
2000	39
4000	38
8000	37

Table XXIII. Intermittent noise limits

Rack Noise Limits Measured at 0.6 meters distance from the test article	
Maximum Rack Noise Duration Ü	Total Rack A-weighted SPL (dBA)
8 Hours	49
7 Hours	50
6 Hours	51
5 Hours	52
4 Hours	54
3 Hours	57
2 Hours	60
1 Hour	65
30 Minutes	69
15 Minutes	72
5 Minutes	76
2 Minutes	78
1 Minute	79
Not Allowed	80

The Rack Noise Duration is the total time that the rack produces intermittent noise above the NC-40 limit during a 24-hr time period. This duration is the governing factor in determining the allowable Intermittent Noise Limits. Regardless of the number of separate sources and varying durations within a rack, this cumulative duration shall be used to determine the A-weighted SPL limit in column B.

For example, if a rack produces 65 dBA for 30 min in a start-up and warm-up mode and then settles down to 60 dBA for a 1-hr period of normal data acquisition, the duration is 1.5 hr. To meet the requirement, the noise can be no greater than 60 dBA, and in this case, the rack would not meet the requirement, even though two separate payloads, one that operated at 65 dBA for 30 min and another that operated at 60 dBA for 1 hr, would be acceptable (see Figure 49).

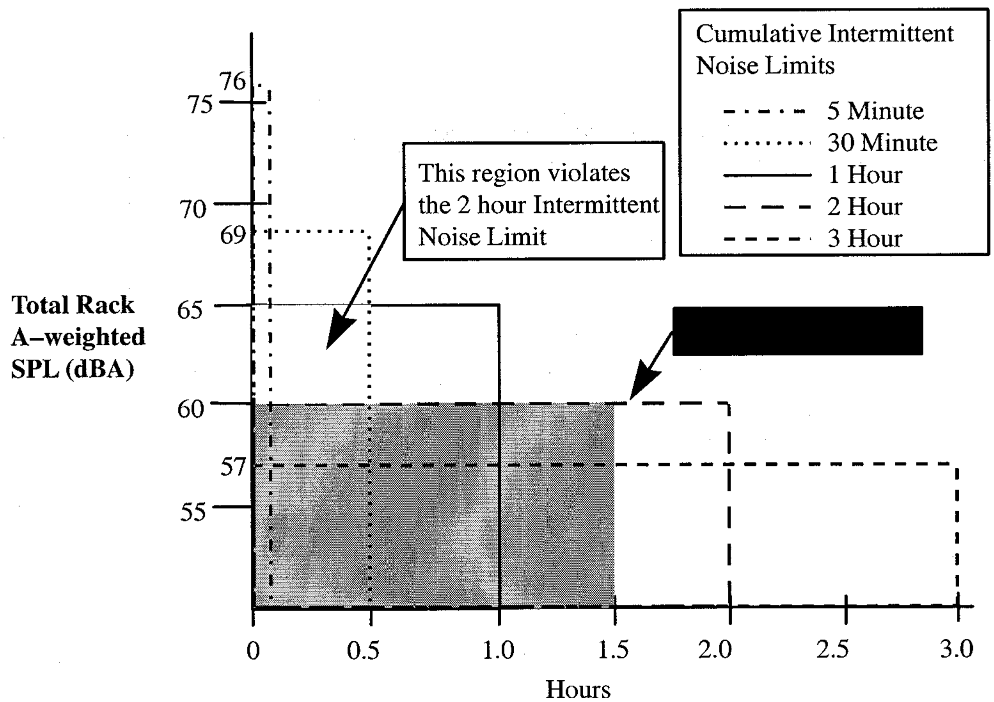


Figure 49. Intermittent noise limits

3.3.7.9 FIR hardware mounting.

3.3.7.9.1 Equipment mounting.

Equipment items used during nominal operations and planned maintenance shall be designed, labeled, or marked to protect against improper installation.

3.3.7.9.2 Drawers and hinged panel.

FIR assemblies, which are pulled out of their installed positions for routine checkout, shall be mounted on equipment drawers or on hinged panels. Such drawers or hinged panels shall remain in the "open" position without being supported by hand.

3.3.7.9.3 Alignment.

FIR hardware having blind mate connectors shall provide guide pins or their equivalent to assist in alignment of hardware during installation.

3.3.7.9.4 Slide-out stops.

Limit stops shall be provided on slide or pivot mounted FIR hardware, which is required to be pulled out of its installed positions.

3.3.7.9.5 Push-pull force.

FIR hardware mounted into a capture-type receptacle that requires a push-pull action shall require a force less than 156 N (35 lbf) to install or remove.

3.3.7.9.6 Access.

Access to inspect or replace a hardware item (e.g., an assembly) which is planned to be accessed on a daily or weekly basis shall not require removal of another hardware item or more than one access cover.

3.3.7.9.7 Covers.

Where physical access is required, one of the following practices shall be followed, with the order of preference given:

a. Provide a sliding or hinged cap or door where debris, moisture, or other foreign materials might otherwise create a problem.
b. Provide a quick-opening cover plate if a cap will not meet stress requirements.

3.3.7.9.8 Self-supporting covers.

All access covers that are not completely removable shall be self-supporting in the open position.

3.3.7.9.9 Unique tools.

Payload provided unique tools shall meet the requirements of SSP 50005, paragraph 11.2.3.

3.3.7.10 Connectors.

3.3.7.10.1 One-handed operation.

All assembly connectors, whether operated by hand or tool, shall be designed and placed so they can be mated/demated using either hand.

3.3.7.10.2 Accessibility.

a.
   1. Nominal Operations – It shall be possible to mate/demate individual connectors without having to remove or mate/demate other connectors.
   2. Maintenance Operations – It shall be possible to mate/demate individual connectors without having to remove or mate/demate connectors on other assemblies or payloads.

b. Electrical connectors and cable installations shall permit disconnection and reconnection without damage to wiring connectors.

3.3.7.10.3 Ease of disconnect.

a. Electrical connectors which are mated/demated during nominal operations shall require no more than two turns to disconnect.
b. Electrical connectors which are mated/demated only during assembly replacement operations shall require no more than six turns to disconnect.

3.3.7.10.4 Indication of pressure/flow.

FIR liquid or gas lines not equipped with quick disconnect connectors which are designed to be connected/disconnected under pressure shall be fitted with pressure/flow indicators.

3.3.7.10.5 Self locking.

Payload electrical connectors shall provide a self-locking feature.

3.3.7.10.6 Connector arrangement.

a. Space between connectors and adjacent obstructions shall be a minimum of 25 mm (1 in.) for IVA access.
b. Connectors in a single row or staggered rows which are removed sequentially by the crew (IVA) shall provide 25 mm (1 in.) of clearance from other connectors and/or adjacent obstructions for 270 degrees of sweep around each connector beginning at the start of its removal/replacement sequence.

3.3.7.10.7 Arc containment.

Electrical connector plugs shall be designed to confine/isolate the mate/demate electrical arcs or sparks.

3.3.7.10.8 Connector protection.

Protection shall be provided for all demated connectors against physical damage and contamination.

3.3.7.10.9 Connector shape.

FIR external and internal connectors shall use different connector shapes, sizes, or keying to prevent mating connectors when lines differ in content.

3.3.7.10.10 Fluid and gas line connectors.

Fluid and gas connectors that are mated and demated on-orbit shall be located and configured so that they can be fully inspected for leakage.

3.3.7.10.11 Alignment marks or pin guides.

Mating parts shall have alignment marks in a visible location during mating or guide pins (or their equivalent).

3.3.7.10.12 Orientation.

Grouped plugs and receptacles shall be oriented so that the aligning pins or equivalent devices are in the same relative position.

3.3.7.10.13 Hose/cable restraints.

a. The FIR shall provide a means to restrain the loose ends of hoses and cables.
b. Conductors, bundles, or cables shall be secured by means of clamps unless they are contained in wiring ducts or cable retractors.
c. Cables shall be bundled if multiple cables are running in the same direction and the bundling does not cause electromagnetic interference (EMI).
d. Loose cables (longer than 0.33 m (1 ft) shall be restrained as follows:

Length (m)	Restraint Pattern ((% of length) tolerances +/– 10%)
0.33–1.00	50
1.00–2.00	33, 67
2.00–3.00	20, 40, 60, 80
>3.00	at least each 0.5 m

3.3.7.11 Fasteners.

3.3.7.11.1 Non-threaded fasteners status indication.

An indication of correct engagement (hooking, latch fastening, or proper positioning of interfacing parts) of non-threaded fasteners shall be provided.

3.3.7.11.2 Mounting bolt/fastener spacing.

Clearance around fasteners to permit fastener hand threading (if necessary) shall be a minimum of 0.5 in. for the entire circumference of the of the bolt head and a minimum of

1.5 in. over 180 degrees of the bolt head and provide the tool handle sweep as seen in Figure 50.

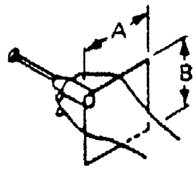
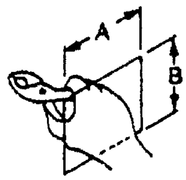
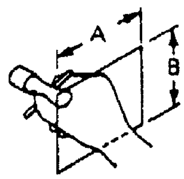
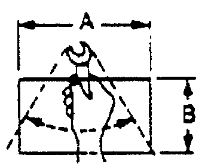
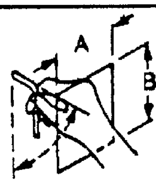
Opening dimensions		Task
	A 117 mm (4.6 in) B 107 mm (4.2 in)	Using common screw-driver with freedom to turn hand through 180°
	A 133 mm (5.2 in) B 115 mm (4.5 in)	Using pliers and similar tools
	A 155 mm (6.1 in) B 135 mm (5.3 in)	Using T-handle wrench with freedom to turn wrench through 180°
	A 203 mm (8.0 in) B 135 mm (5.3 in)	Using open-end wrench with freedom to turn wrench through 62°
	A 122 mm (4.8 in) B 155 mm (6.1 in)	Using Allen-type wrench with freedom to turn wrench through 62°

Figure 50. Minimal clearance for tool-operated fasteners

3.3.7.11.3 Multiple fasteners.

When several fasteners are used on one item, they shall be of identical type.

3.3.7.11.4 Captive fasteners.

All fasteners planned to be installed and/or removed on orbit shall be captive when disengaged.

3.3.7.11.5 Quick release fasteners.

a. Quick release fasteners shall require a maximum of one complete turn to operate (quarter-turn fasteners are preferred).
b. Quick release fasteners shall be positive locking in open and closed positions.

3.3.7.11.6 Threaded fasteners.

Only right-handed threads shall be used.

3.3.7.11.7 Over center latches.

a. Non-self-latching – Over center latches shall include a provision to prevent undesired latch element realignment, interface, or reengagement.
b. Latch lock – Latch catches shall have locking features.
c. Latch handles – If the latch has a handle, the latch handle and latch release shall be operable by one hand.

3.3.7.11.8 Winghead fasteners.

Winghead fasteners shall fold down and be retained flush with surfaces.

3.3.7.11.9 Fastener head type.

a. Hex type external or internal grip or combination head fasteners shall be used where on-orbit crew actuation is planned, e.g., assembly replacement.
b. If a smooth surface is required, flush or oval head internal hex grip fasteners shall be used for fastening.
c. Slotted fasteners shall not be used to carry launch loads for hard-mounted equipment. Slotted fasteners are allowed in non-structural applications (e.g., computer data connectors, stowed commercial equipment).
   Note: Phillips or Torque-Set fasteners may be used where fastener installation is permanent relative to planned on-orbit operations or maintenance, or where tool-fastener interface failure can be corrected by replacement of the unit containing the affected fastener with a spare unit.

3.3.7.11.10 One handed operation.

Fasteners planned to be removed or installed on orbit shall be designed and placed so they can be mated/demated using either hand.

3.3.7.11.11 Access holes.

Covers or shields through which mounting fasteners must pass for attachment to the basic chassis of the unit shall have holes for passage of the fastener without precise alignment (and hand or necessary tool if either is required to replace).

3.3.7.12 Controls and displays.

3.3.7.12.1 Controls spacing design requirements.

All spacing between controls and adjacent obstructions shall meet the minimum requirements as shown in Figure 51.

3.3.7.12.2 Accidental actuation.

3.3.7.12.2.1 Protective methods.

The FIR shall provide protection against accidental control actuation using one or more of the protective methods listed in subparagraphs a through g below. Infrequently used controls (i.e. those used for calibration) should be separated from frequently used controls. Leverlock switches or switch covers are strongly recommended for switches related to mission success. Switch guards may not be sufficient to prevent accidental actuation.

Note: Displays and controls used only for maintenance and adjustments, which could disrupt normal operations if activated, should be protected during normal operations, e.g., by being located separately or guarded/covered.

a. Locate and orient the controls so that the operator is not likely to strike or move them accidentally in the normal sequence of control movements.
b. Recess, shield, or otherwise surround the controls by physical barriers. The control shall be entirely contained within the envelope described by the recess or barrier.
c. Cover or guard the controls. Safety or lock wire shall not be used.
d. Cover guards when open shall not cover or obscure the protected control or adjacent controls.

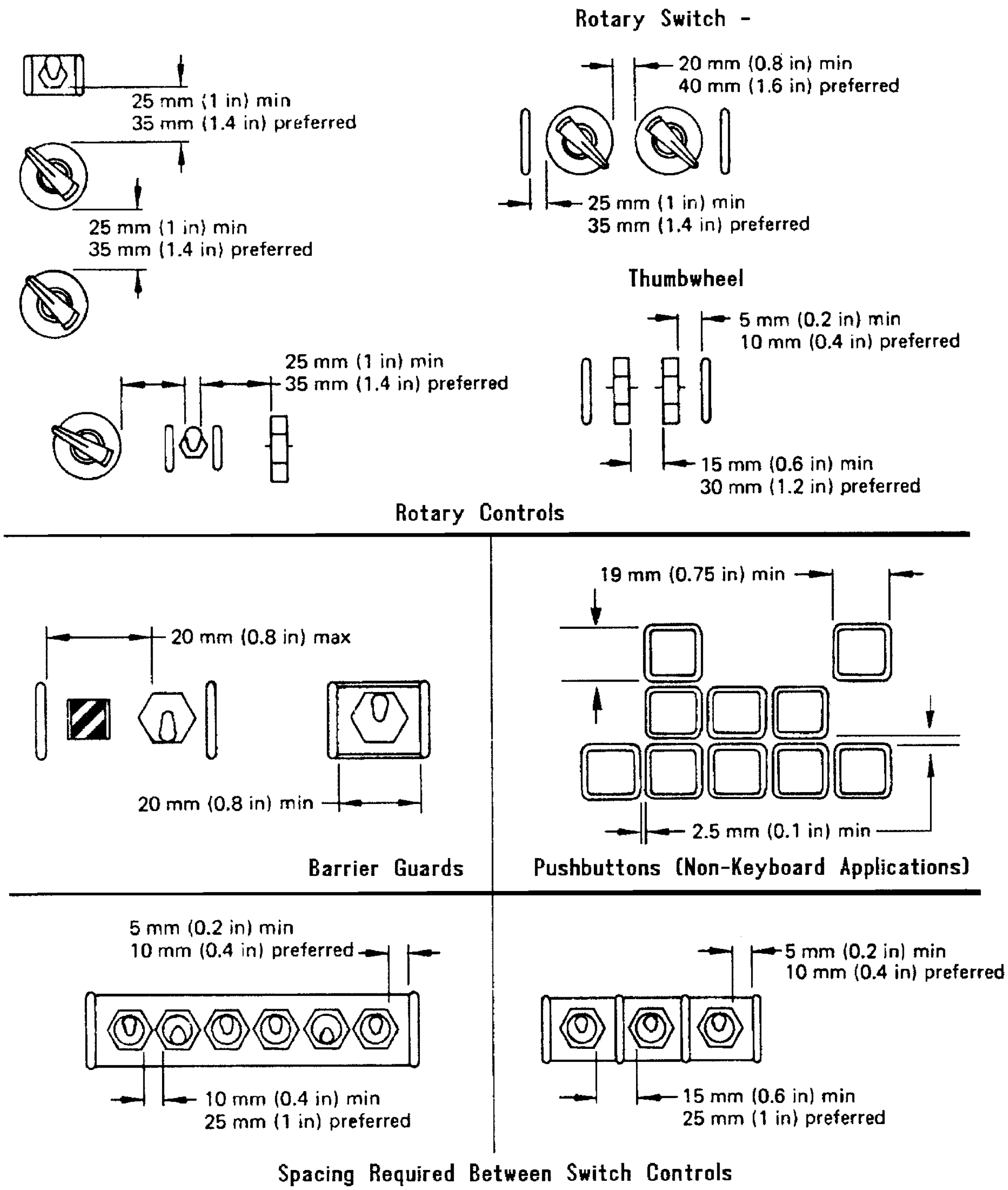


Figure 51. Control spacing requirements for ungloved operation

e. Provide the controls with interlocks so that extra movement (e.g., lifting switch out of a locked detent position) or the prior operation of a related or locking control is required.
f. Provide the controls with resistance (i.e., viscous or coulomb friction, spring-loading, or inertia) so that definite or sustained effort is required for actuation.
g. Provide the controls with a lock to prevent the control from passing through a position without delay when strict sequential actuation is necessary (i.e., the control moved only to the next position, then delayed).

3.3.7.12.2.2 Noninterference.

FIR provided protective devices shall not cover or obscure other displays or controls.

3.3.7.12.2.3 Dead-man controls.

Dead-man controls shall be as specified in NSTS 1700.7 ISS Addendum, paragraphs 200.4 a. and 303.2.

3.3.7.12.2.4 Barrier guards.

Barrier guard spacing shall adhere to the requirements for use with the toggle switches, rotary switches, and thumbwheels as shown in Figure 51 and Figure 52.

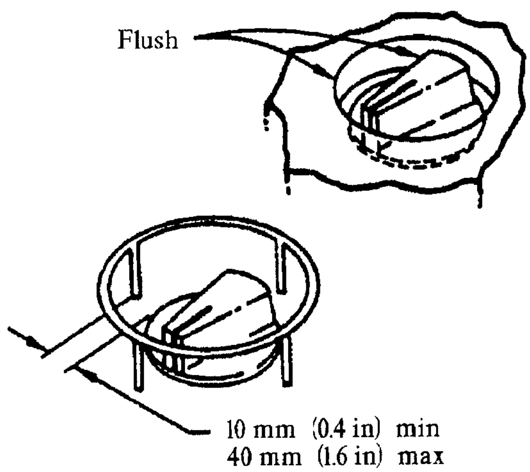


Figure 52. Rotary switch guard

3.3.7.12.2.5 Recessed switch protection.

When a barrier guard is not used, rotary switches that control critical functions shall be recessed as shown in Figure 52.

3.3.7.12.2.6 Position indication.

When FIR switch protective covers are used, control position shall be evident without requiring cover removal.

3.3.7.12.2.7 Hidden controls.

Controls that cannot be directly viewed will be avoided. If present, hidden controls shall be guarded to protect against inadvertent actuation.

3.3.7.12.2.8 Hand controllers.

Hand controllers, excluding trackballs and mice, shall have a separate on/off control to prevent inadvertent actuation when the controller is not in use.

3.3.7.13 Valve controls.

a. Low-Torque Valves – Valves requiring 1 N-m (10 in-lb) or less for operation are classified as “low-torque” valves and shall be provided with a “central pivot” type handle, 5.5 cm (2.25 in.) or less in diameter. (see 3.3.7.13 d.).
b. Intermediate-Torque Valves – Valves requiring between 1 and 2 N-m (10 and 20 in-lb) for operation are classified as “intermediate torque” valves and shall be provided with a “central pivot” type handle, 5.5 cm (2.25 in.) or greater in diameter, or a “lever type” handle, 7.5 cm (3 in.) or greater in length.
c. High-Torque Valves – Valves requiring 2 N-m (20 in-lb) or more for operation are classified as “high-torque” valves and shall be provided “lever type” handles greater than 7.5 cm (3 in.) or greater in length.
d. Handle Dimensions – Valve handles shall adhere to the clearances and dimensions illustrated in Figure 53 and Figure 54.
e. Rotary Valve Controls – Rotary valve controls shall open the valve with a counterclockwise motion.

3.3.7.14 Toggle switches.

Dimensions for a standard toggle switch shall conform to the values presented in Figure 55.

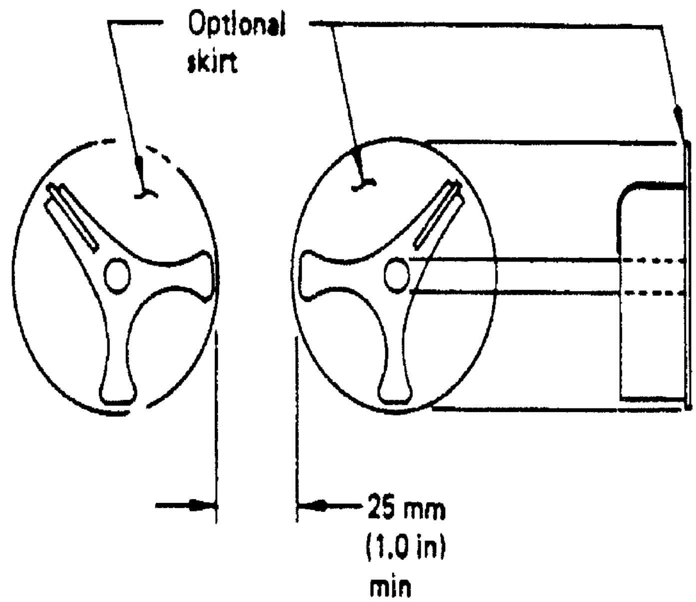


Figure 53. Valve handle – central pivot type

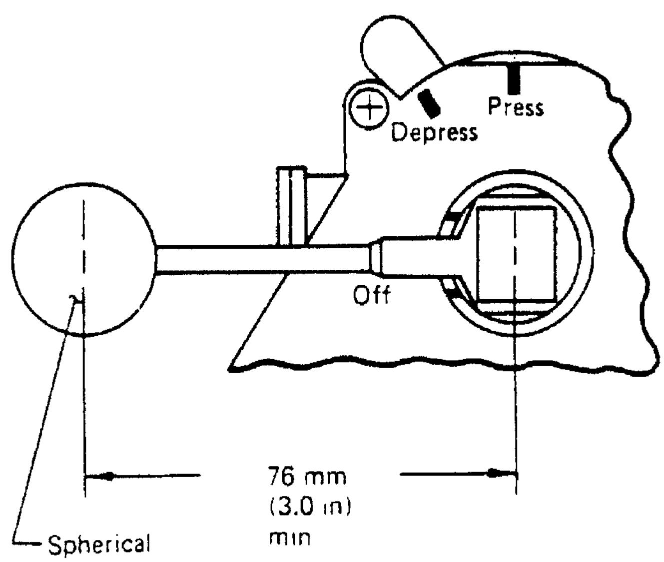
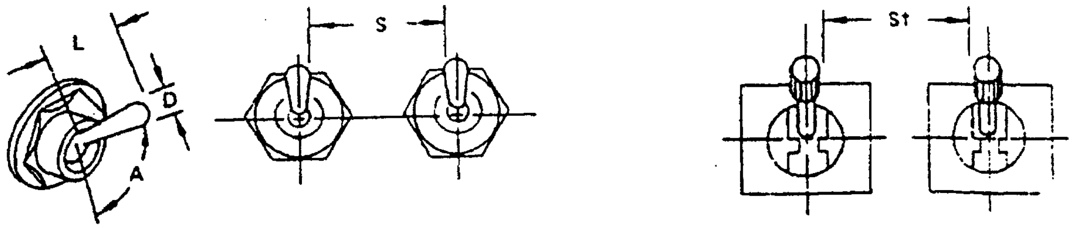


Figure 54. Valve handle – lever type



	Dimensions		Resistance	
	L Arm length	D Control tip	Small switch	Large switch
Minimum	13 mm (1/2 in)	3mm (1/8 in)	2.8 N (10 oz)	2.8 N (10 oz)
Maximum	50 mm (2 in)	25 mm (1 in)	4.5 N (16 oz)	11 N (40 oz)

	Displacement between positions A	
	2 position	3 position
Minimum	30°	17°
Maximum	80°	40°
Desired		25°

	Separation S			
	Single finger operation	†	Single finger sequential operation	Simultaneous operation by different fingers
Minimum	19 mm (3/4 in)	25 mm (1 in)	13 mm (1/2 in)	16 mm (5/8 in)
Optimum	50 mm (2 in)	50 mm (2 in)	25 mm (1 in)	19 mm (3/4 in)

† Using a lever lock toggle switch

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Reference: 2, page 93

Figure 55. Toggle switches

3.3.7.15 Restraints and mobility aids.

The FIR shall be designed such that all installation, operation, and maintenance can be performed using standard crew restraints, mobility aids, and interfaces as defined in SSP 30257:004.

3.3.7.16 Captive parts.

The FIR equipment shall be designed in such a manner to ensure that all unrestrained parts (e.g., locking pins, knobs, handles, lens covers, access plates, or similar devices) that may be temporarily removed on orbit will be tethered or otherwise held captive.

3.3.7.17 Handle and grasp area design requirements.

3.3.7.17.1 Handles and restraints.

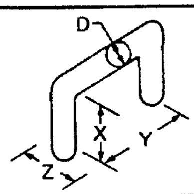
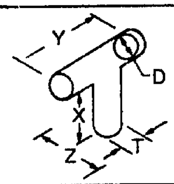
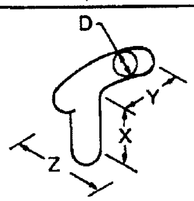
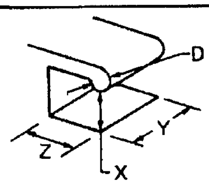
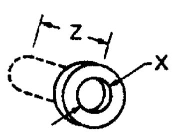
All removable or portable items which cannot be grasped with one hand shall be provided with handles or other suitable means of grasping, tethering, carrying, and restraining.

3.3.7.17.2 Handle location/front access.

Handles and grasp areas shall be placed on the accessible surface of a payload item consistent with the removal direction.

3.3.7.17.3 Handle dimensions.

IVA handles for movable or portable units shall be designed in accordance with the minimum applicable dimensions in Figure 56.

Illustration	Type of handle	Dimensions in mm (in inches) (Bare hand) X	Y	Z
	*Two-finger bar* One-hand bar Two-hand bar	32 (1–1/4) 48 (1–7/8) 48 (1–7/8)	65 (2–1/2) 111 (4–3/8) 215 (8–1/2)	75 (3) 75 (3) 75 (3)
	T-bar	38 (1–1/2)	100 (4)	75 (3)
	J-bar	50 (2)	100 (4)	75 (3)
	Two-finger recess One-hand recess	32 (1–1/4) 50 (2)	65 (2–1/2) 110 (4–1/4)	75 (3) 90 (3–1/2)
	Finger-tip recess One-finger recess	19 (3/4) 32 (1–1/4)	– –	13 (1/2) 50 (2)

Curvature of handle or edge	Weight of Item	Minimum diameter	
(DOES NOT PRECLUDE USE OF OVAL HANDLES)	Up to 6.8 kg (up to 15 lbs) 6.8 to 9.0 kg (15 to 20 lbs) 9.0 to 18 kg (20 to 40 lbs) Over 18 kg (over 40 lbs) T-bar post	D = 6 mm (1/4 in) D = 13 mm (1/2 in) D = 19 mm (3/4 in) D = 25 mm (1 in) T = 13 mm (1/2 in)	Gripping efficiency is best if finger can curl around handle or edge to any angle of 2/3 π rad (120°) or more

Figure 56. Minimum IVA handle dimensions for IVA applications

3.3.7.17.4 Nonfixed handles design requirements.

a. Nonfixed handles shall have a stop position for holding the handle perpendicular to the surface on which it is mounted.
b. Nonfixed handles shall be capable of being placed in the use position by one hand and shall be capable of being removed or stowed with one hand.

c. Attachable/removable handles shall incorporate tactile and/or visual indication of locked/unlocked status.

3.3.8 Design requirements.

3.3.8.1 Units of measure.

The FIR shall use metric units as its primary unit of measure, except when interfacing with non-metric ISS equipment or lack of availability of metric components precludes it.

3.3.8.2 Margins of safety/factor of safety.

The design of the FIR shall use factors of safety as specified in NSTS 1700.7, NSTS 1700.7, ISS Addendum, and SSP 52005.

3.3.8.3 Allowable mechanical properties.

Values for mechanical properties of structural materials in their design environment shall be taken in accordance with MIL-HDBK-05 and MIL-HDBK-27 using the "A" allowable.

3.3.8.4 Fracture control.

The FIR structure shall meet the fracture control requirements as specified in NASA-STD-5003.

3.4 FIR computer resource requirements.

In addition to the computer resource requirements specified in paragraph 3.2, the FIR shall meet the requirements in this section.

3.4.1 FIR computer software design considerations.

a. The FIR primary processor shall be capable of self-activation and self-test once power is applied to the FIR power interface.
b. The FIR shall verify the integrity of all transmitted files.
c. A single computer within the FIR shall coordinate all automated activities performed by the FIR.

3.4.1.1 Command and data requirements.

3.4.1.1.1 Word/byte notations.

The FIR shall use the word/byte notations as specified in SSP 52050, paragraph 3.1.1.

3.4.1.1.2 Data types.

The FIR shall use the data types as specified in SSP 52050, paragraph 3.2.1 and subparagraphs.

3.4.1.1.3 Data transmissions.

a. The FIR data transmission on low rate data link (LRDL), MIL-STD-1553B shall use the data transmission order in accordance with D684-10056-01, paragraph 3.4.
b. The FIR data transmission on medium rate data link (MRDL) shall use the data transmission order in accordance with SSP 52050, paragraph 3.3.3.1.
c. The FIR data transmission on high rate data link (HRDL) shall use the data transmission order in accordance with CCSDS 701.0-B-2, paragraph 1.6.

3.4.1.1.4 Consultative committee for space data systems.

a. FIR data that is space to ground shall be Consultative Committee for Space Data Systems (CCSDS) data packets.
b. FIR data that is ground to space shall be CCSDS data packets.
c. FIR to Payload MDM data shall be CCSDS data packets.

3.4.1.1.4.1 CCSDS data packets.

FIR data packets shall be developed in accordance with SSP 52050, paragraph 3.1.3. FIR CCSDS data packets consist of a primary header and a secondary header followed by the data field.

3.4.1.1.4.1.1 CCSDS primary header.

FIR shall develop a CCSDS primary header in accordance with SSP 52050, paragraph 3.1.3.1.

3.4.1.1.4.1.2 CCSDS secondary header.

a. The FIR shall develop a CCSDS secondary header immediately following the CCSDS primary header.
b. The CCSDS secondary header shall be developed in accordance with SSP 52050, paragraph 3.1.3.2.

3.4.1.1.4.1.3 CCSDS data field.

The FIR CCSDS data field shall contain the FIR data from the transmitting application to the receiving application, and the CCSDS checksum in accordance with SSP 52050, paragraph 3.1 and subparagraphs.

3.4.1.1.4.1.4 CCSDS application process identification field.

The CCSDS application process identification (APID) shall be used for routing data packets as described in SSP 41175-2, paragraph 3.3.2.1.3. The format of APID is shown in SSP 41175-2, Table 3.3.2.1.1–1.

3.4.1.1.4.2 CCSDS time codes.

3.4.1.1.4.2.1 CCSDS unsegmented time.

FIR shall use CCSDS unsegmented time code (CUC) in the secondary header as specified in CCSDS 301.0-B-2, paragraph 2.2.

3.4.1.1.4.2.2 CCSDS segmented time.

Segmented time code shall be sent to the integrated rack by a broadcast message on the Payload MIL-STD-1553B. Segmented time code formats are specified in CCSDS 301.0-B-2, paragraph 2.4.

The broadcast time will be received at subaddress #29 on each Payload MIL-STD-1553B bus.

3.4.1.1.5 MIL-STD-1553B low rate data link (LRDL).

The FIR shall implement a single MIL-STD-1553B Remote Terminal (RT) to the payload unique MIL-STD-1553B bus in accordance with SSP 52050, paragraph 3.2.

3.4.1.1.5.1 Standard messages.

The FIR shall develop standard messages for the Payload MIL-STD-1553B in accordance with SSP 52050, paragraph 3.2.3.3.

3.4.1.1.5.2 Commanding.

The FIR shall receive and process commands from the Payload MDM that originate from the Ground, Timeliner, Payload MDM, and Portable Computer System (PCS) in accordance with SSP 52050, paragraph 3.2.3.4.

3.4.1.1.5.3 Health and status data.

a. The FIR shall develop health and status data in accordance with SSP 52050, paragraph 3.2.3.5.
b. The health and status data shall be documented in accordance with the data field format defined in SSP 57002, Table A–5. The definition of health and status data is provided in the Glossary of Terms, Appendix B of this document.

c. The FIR shall respond to its respective FIR MDM polls for health and status data with updated data at a 1 Hz or 0.1 Hz rate.

3.4.1.1.5.4 Safety data.

a. Safety data shall be included in the health and safety data CCSDS packets provided by ISPR Remote Terminals (RTs).
b. The FIR shall provide as safety data the standard rack caution and warning status words in accordance with SSP 52050, paragraph 3.2.3.5.

3.4.1.1.5.5 Caution and warning.

3.4.1.1.5.5.1 Class 2 – warning.

The FIR shall format the caution and warning word in accordance with SSP 52050, paragraph 3.2.3.5 as a warning when the FIR sensors detect the following conditions:

1. A potential fire event, (detected by a sensor other than an ISS rack smoke detector or equivalent).
2. A precursor event that could manifest to an emergency condition (toxic atmosphere, rapid cabin depressurization or fire) and
   (a) Automatic safing has failed to safe the event or
   (b) The system is not automatically safed (i.e. requires manual intervention).
4. An event that results in the loss of a hazard control and
   (a) Automatic safing has failed to safe the event or
   (b) The system is not automatically safed (i.e. requires manual intervention).

Note: A warning requires someone to take action immediately. Warnings are used for events that require manual intervention and for notification when automatic safing fails.

3.4.1.1.5.5.2 Class 3 – caution.

The FIR shall format the caution and warning word in accordance with SSP 52050, paragraph 3.2.3.5 as a caution when the FIR sensors detect the following conditions:

1. A precursor event that could manifest to an emergency condition (toxic atmosphere, rapid cabin depressurization, or fire) and automatic safing has safed the event (i.e. the system does not require manual intervention).
2. An event that results in the loss of a hazard control and automatic safing has safed the event (i.e., the system does not require manual intervention).

Note: A caution requires no immediate action by the crew. Automatic safing has controlled the event.

3.4.1.1.5.5.3 Class 4 – advisory.

The FIR shall format the caution and warning word in accordance with SSP 52050, paragraph 3.2.3.5 as an advisory. Advisories are set for the following conditions:

1. Advisories are set primarily for ground monitoring purposes (advantageous due to limited comm. Coverage and data recording).
2. Data item that most likely will not exist permanently in Telemetry List but should be time tagged and logged for failure isolation, trending, sustaining engineering, etc.

3.4.1.1.5.6 Service requests.

The FIR shall develop service requests that shall be in accordance with SSP 52050, paragraph 3.2.3.7. The service requests data format shall be developed in accordance with SSP 52050, Table 3.2.3.7–1.

3.4.1.1.5.7 File transfer.

The FIR shall develop its file transfer in accordance with SSP 52050, paragraph 3.2.3.9.

3.4.1.1.5.8 Low rate telemetry.

The FIR shall develop low rate telemetry (i.e. science data) in accordance with SSP 52050, paragraph 3.2.3.10.

3.4.1.1.5.9 Defined mode codes.

FIR MIL-STD-1553B shall use the mode codes as specified in SSP 52050, paragraph 3.2.3.2.1.5.

3.4.1.1.5.10 Implemented mode codes.

The FIR MIL-STD-1553B Remote Terminal (RT) may be designed to recognize both unimplemented and undefined mode codes as illegal commands. If the RT designer does decide to monitor for unimplemented/undefined code modes, the RT shall respond by setting the message error bit in the status word.

3.4.1.1.5.11 Illegal commands.

The FIR MIL-STD-1553B RTs are not required to respond to illegal commands. If an RT designed with this option detects an illegal command, it shall respond to the illegal command by setting the message error bit in the status word.

3.4.1.1.5.12 LRDL interface characteristics.

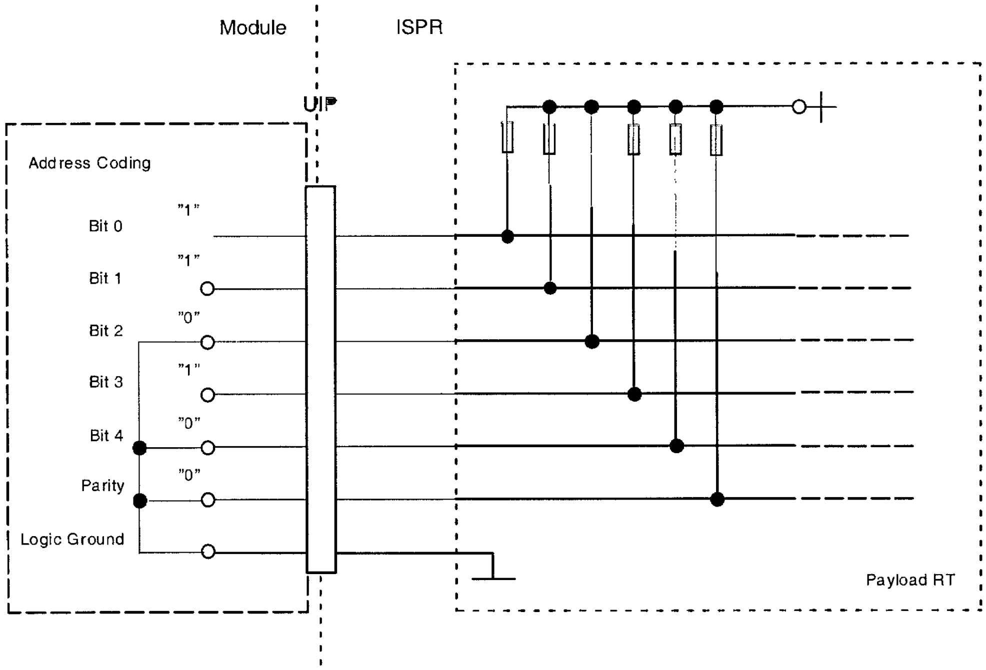
a. FIR connectors P3 and P4 shall meet the pinout interfaces of the UIP J3 and J4 connectors respectively as specified in SSP 57001, paragraph 3.3.2.2.
b. FIR connectors P3 and P4 shall meet the requirements of SSQ 21635 or equivalent.

3.4.1.1.5.12.1 Remote terminal hardwired address coding.

a. The FIR shall be designed to read and respond to the hardware Remote Terminal address coding scheme for the Standard Payload Bus, for all ISPR locations defined in Table XXIV. Details of the implementation of the payload Remote Terminals are illustrated in Figure 57.
b. Decimal values shall be mapped in 5 bit presentation, bit 0 = Least Significant Bit (LSB), see Figure 57.
c. Odd-parity shall be used.
d. Jumpering address line to ground shall be logic 0.
e. Pull up devices, shown in Figure 57, shall be in accordance with MIL-STD-1553B.

Table XXIV. Remote terminal hardwired address coding for standard payload bus

APM ISPR		JEM ISPR		USL ISPR		CAM ISPR	
Location	RT Hardwired Address	Location	RT Hardwired Address	Location	RT Hardwired Address	Location	RT Hardwired Address
APM1F1	15	JPM1F1	15	LAB101	8	CAM1F2 (TBC)	20
APM1F2	16	JPM1F2	16	LAB102	9	CAM1F3 (TBC)	21
APM1F3	17	JPM1F3	17	LAB103	10	CAM1A2 (TBC)	20
APM1F4	18	JPM1F5	18	LAB104	11	CAM1A3 (TBC)	21
APM1A1	19	JPM1F6	19	LAB105	12	CAM1A3 (TBC)	**(TBD #9)**
APM1A2	20	JPM1A1	20	LAB1S1	8		
APM1A3	21	JPM1A2	21	LAB1S2	9		
APM1A4	22	JPM1A3	22	LAB1S3	10		
APM101	23	JPM1A4	23	LAB1S4	11		
APM102	24	JPM1A5	24	LAB1D3	14		
				LAB1P1	12		
				LAB1P2	15		
				LAB1P4	17		



Note: Example RT Address = 11 in decimal representation.
All address and parity lines have pull up resistors so that "0" on those lines is achieved by connecting the lines to common secondary return. The parity is odd. Bit 0 is LSB.

Figure 57. Remote terminal hardwired address coding example

3.4.1.1.5.12.2 LRDL signal characteristics.

a. The FIR shall meet the electrical characteristics in accordance with MIL-STD-1553B.
b. The FIR MIL-STD-1553B terminal characteristics shall be in accordance with MIL-STD-1553B, paragraph 4.5.2.

3.4.1.1.5.12.3 LRDL cabling.

a. The FIR MIL-STD-1553B internal wiring characteristics shall be according to SSQ 21655 for 75 Ω or equivalent.
b. The FIR MIL-STD-1553B internal wiring characteristics are summarized in MIL-STD-1553B, Table 3.3.5.2.3–1.
c. The FIR MIL-STD-1553B internal wiring stub length shall not exceed 12 ft (3.65 m) when measured from the internal MIL-STD-1553B Remote Terminal to the ISPR Utility Interface Panel.

Table XXV. MIL-STD-1553B network characteristics

Characteristic	Parameter
Type	Twisted Shielded Pair SSQ 21655 or Equivalent
Characteristic Impedance	75 ± 5 Ohm
Cable Size	22 AWG or 24 AWG
Nominal wire-to-wire Capacitance	66 pf/m

3.4.1.1.5.12.4 Multi-bus isolation.

The signal isolation between multiple ISS Payload MIL-STD-1553B data buses shall be no less than 58 dB.

3.4.1.1.6 Medium rate data link (MRDL).

3.4.1.1.6.1 MRDL protocol.

The FIR shall conform to ISO/IEC 8802-3 10-Base-T protocol in accordance with SSP 52050, paragraph 3.3.

3.4.1.1.6.2 FIR protocols on the MRDL.

a. The FIR shall conform to ISO/IEC 8802-3 10-Base-T protocol in accordance with SSP 52050, paragraph 3.3.
b. The FIR shall use the CCSDS protocol and gateway protocol in SSP 52050, paragraphs 3.3.4 and 3.3.7.

3.4.1.1.6.3 MRDL address.

a. The FIR shall have a unique Institute of Electrical and Electronic Engineers (IEEE) issued physical address.
b. The unique address shall be set prior to the Ethernet terminal going active. The FIR will indicate the unique physical address in the FIR ICD.

3.4.1.1.6.4 FIR MRDL connectivity.

a. The FIR with an MRDL connection shall have no more than one physical connection per LAN. An integrated rack with an MRDL connection may have one physical connection to LAN-1 and one physical connection to LAN-2. LAN-1 is located in J46 and LAN-2 is located in J47.
b. The FIR shall not route or transmit the same MRDL message to the ISS LANs simultaneously.

c. The FIR with internal MRDL(s) shall provide isolation between the ISS MRDL LAN's and the internal LAN's with either an Ethernet Bridge or an Internet Protocol router that connects the LAN-1 and LAN-2 to the internal rack LAN(s).
d. The Ethernet device connected to the ISS LAN shall have a (unique) IEEE issued address.

3.4.1.1.6.5 MRDL connector/pin assignments and wire requirements.

a. The FIR connectors P46 and P47 shall meet the pinout interfaces of the UIP J46 and J47 connectors as specified in SSP 57001, paragraph 3.3.3.1.
b. FIR LAN-1 and LAN-2 connectors P46 and P47 shall meet the requirements of SSQ 21635 or equivalent.
c. FIR LAN-1 and LAN-2 wires shall meet the requirements of 100 Ω twisted-pair per SSQ 21655 or equivalent. The 100 Ω twisted shielded pair cable defined in SSQ 21655 must be used due to its characteristics at MRDL data transmission frequencies.

3.4.1.1.6.6 MRDL signal characteristics.

The FIR shall meet the electrical characteristics of MRDL in accordance with ISO/IEC 8802-3 with the following exceptions:

IEC Publication	60	High-Voltage Test Techniques
IEC Publication	380	Safety of Electrically Energized Office Machines
IEC Publication	435	Safety of Data Processing Equipment
IEC Publication	950	Safety of Information Technology Equipment, Including Electrical Business Equipment

3.4.1.1.6.7 MRDL cable characteristics.

The MRDL cable characteristics shall be as given in Table XXVI.

Characteristic	Parameter
Characteristic Impedance	100 ±7 Ohm
Cable Size	22 AWG
Type of Cable	Twisted Shielded Pair SSQ 21655 or Equivalent
Nominal wire-to-wire Capacitance	45 pF/m
Max Cable Length in ISPR	5 m

Table XXVI. Link segment cable characteristics

3.4.1.1.6.7.1 Differential characteristic impedance.

The ISPR differential characteristic impedance shall meet the requirements specified in ISO/IEC 8802-3, paragraph 14.4.2.2 with the exception that the wire meets the performance characteristics in Table XXVII.

Table XXVII. NTSC video performance characteristics.

Characteristic	End-to-End Path Characteristics	Test Method
Amplitude vs. Frequency	10 KHz to 300 KHz: ±0.2 dB at 3.58 Mhz ± 300 Khz :±0.4 dB to 4.2 Mhz: ±0.7 dB (A) to 10 Mhz: +1/–3 dB	EIA/TIA – 250C Para 6.1.1
Chrominance to Luminance Gain Inequality	± 4.0 IRE units	EIA/TIA – 250C Para 6.1.2.1
Chrominance to Luminance Delay Inequality	± 26 ns	EIA/TIA – 250C Para 6.1.2.2
Field Time Waveform Distortion	3 IRE units peak-to-peak	EIA/TIA – 250C Para 6.1.4
Line Time Waveform Distortion	1 IRE unit peak-to-peak	EIA/TIA – 250C Para 6.1.5
Short Time Waveform Distortion	2.0%	EIA/TIA – 250C Para 6.1.1
Long Time Waveform Distortion	8 IRE units overshoot Max. setting to 5 IRE units after 3 Sec.	EIA/TIA – 250C Para 6.1.7
Line-By-Line DC Offset	± 2.0 IRE Max.	
Insertion Gain and Variation	± 0.2 dB	EIA/TIA – 250C Para 6.1.8
Luminance Non-Linearity	6% Max	EIA/TIA – 250C Para 6.2.1
Differential Gain	4% Max	EIA/TIA – 250C Para 6.2.2.1
Differential Phase	1.9 degrees	EIA/TIA – 250C Para 6.2.2.2
Chrominance to Luminance Intermodulation	2.0 IRE	EIA/TIA – 250C Para 6.2.3
Chrominance Non-Linear Gain	2.0 IRE	EIA/TIA – 250C Para 6.2.4.1
Chrominance Non-Linear Phase	2.0 degrees	EIA/TIA – 250C Para 6.2.4.2
Dynamic Gain of the Picture Signal	4.0 IRE	EIA/TIA – 250C Para 6.2.5.1
Dynamic Gain of the Synchronizing Signal	2.0 IRE	EIA/TIA – 250C Para 6.2.5.2
Transient Synchronizing Signal Non-Linearity	3.0 IRE	EIA/TIA – 250C Para 6.2.6
Signal to Noise Ratio (10 KHz to 5 MHz) (Triangular)	43.8 dB min, unweighted	EIA/TIA – 250C Para 6.3.1
Signal to Noise Ratio (10 KHz to 10 MHz) (Triangular)	36.6 dB min, unweighted	EIA/TIA – 250C Para 6.3.1
Signal to Low Frequency Noise (0–10 kHz)	50 dB min, unweighted	EIA/TIA – 250C Para 6.3.2
Signal to Periodic Noise Ratio (300 Hz to 4.2 MHz)	63 dB min, unweighted	EIA/TIA – 250C Para 6.3.3
2T Short Time Distortion	± 4.0 IRE units	NTC–7 Para 3.5
Group Delay (5 to 10 MHz)	150 ns	

Note

(A) Monotonic roll off beyond 4.2 Min MHz.

3.4.1.1.7 FIR to high-rate frame multiplexer (HRFM) protocols.

The FIR shall use the HRFM common protocols in accordance with SSP 50184, paragraph 3.3.2.

3.4.1.1.7.1 High rate data link (HRDL) physical signaling data rates.

a. The FIR shall be designed to transmit data on the HRDL with adjustable data rates in between 0.5 and 95 Mbps.
b. The FIR HRDL data rate shall be adjustable in increments of 0.5 Mbps.
c. Transmitted data shall be designed to be “evenly parsed” in accordance with SSP 50184, paragraph 3.3.1.3.2.

Note:

1. The HRDL is a shared resource on the ISS. The HRDL data is sent to the ground through the HRFM. When a payload has the entire HRFM capacity assigned to that payload, the Maximum HRDL Data Rate is approximately 43 Mbps. Under normal conditions the payload shares the 43 Mbps with 11 other data sources. The actual HRDL data rate designed into the payload is subject to planning.
2. The FIR maximum designed data rate is subject to planning.
3. The FIR is not required to implement every possible increment in the negotiated range. For example, an integrated rack may choose to implement 0.5, 1.0, 2.0, 4.0, 8.0, and 16.0 Mbps for a planned range of 0.5 to 16.0 Mbps.
4. The data rate tolerance is under investigation.
5. The FIR may use any HRDL data rate desired in a multi-location payload where the source payload and the destination payload for the HRDL data is developed by one payload project.

3.4.1.1.7.2 Encoding.

The FIR shall encode the HRDL data in accordance with SSP 50184, paragraph 3.1.3; SSP 50184, paragraph 3.1.3.1; SSP 50184, Table 3.1.3.1–1; and SSP 50184, paragraph 3.1.3.2.

3.4.1.1.7.3 Symbols used in testing.

The FIR shall provide the Halt symbol (H) in accordance with SSP 50184, Table 3.1.3.1–1for use in optical power tests.

3.4.1.1.7.4 FIR HRDL transmitted optical power.

a. The FIR shall be designed to transmit a HRDL signal in accordance with SSP 50184, paragraph 3.1.1 at an average optical power greater than –16.75 dBm and less than –8.3 dBm.
b. The FIR transmitted optical power shall be measured at the FIR P7 connector to the ISPR connector interface panel using the Halt symbol.

3.4.1.1.7.5 HRDL fiber optic cable.

The FIR shall use fiber optic cable in accordance with SSQ 21654.

3.4.1.1.7.6 HRDL fiber optic bend radius.

The FIR shall develop the routing, installation, and handling procedures to assure the minimum bend radius of 2 in. or greater is maintained at all times for the fiber optic cable.

3.4.1.1.7.7 HRDL connectors and fiber.

a. The FIR connector P7 shall meet the pinout interfaces of the UIP J7 connector as specified in SSP 57001, paragraph 3.3.4.1.
b. The FIR HRDL connector P7 shall meet the requirements of SSQ 21635 or equivalent.
c. The FIR HRDL fiber shall meet the requirements of SSQ 21654 or equivalent.

3.4.1.1.8 Station support computer (SSC).

a. The FIR shall be limited to one shared SSC. The SSC is not dedicated to a rack; memory and hard drive availability for payload displays and software must be negotiated with the Payload Software Control Panel.
b. SSC displays shall be in accordance with SSP 50313 (not unique to SSC).

3.4.1.1.9 FIR national television systems committee (NTSC) video and audio interface requirements.

3.4.1.1.9.1 FIR NTSC video characteristics.

a. FIR NTSC video characteristics shall be in accordance with Table XXVII.
b. The interpretation shall be in accordance with EIA/TIA RS-250-C End to End NTSC Video for Satellite Transmission System.
c. Video signal to crosstalk noise shall be in accordance with NTC-7, paragraph 3.19.

3.4.1.1.9.2 Pulse frequency modulation NTSC fiber optic video characteristics.

a. The pulsed frequency modulation (PFM) fiber optic video shall be in accordance with paragraph 3.4.1.1.9.1.
b. The PFM fiber optic characteristics shall be in accordance with Table XXVIII.

Table XXVIII. NSTS fiber optic video signal characteristics.

PFM Signal Bandwidth	40–72 Megahertz (MHz)
PFM Signal Characteristics	Square wave, FM signal characterized by nominal 50 percent duty cycle
PFM Center Frequency (Blanking Level)	48.57 MHz (0 IRE/0mV)
White Level Frequency	70.25 Mhz (100 IRE/714 mV)
Sync Tip Frequency	40.07 Mhz (–40 IRE/–286 mV)
Blanking Level Variation	+/– 2 Mhz
Video Signal Format	NTSC composite NTSC/EIA–RSA–170A (1)
Pre-emphasis/De-emphasis	per CCIR Recommendation 405 of EIA/TIA–250–C. (1) (2)
Bus Media	Fiber Optics on both SSMB and APM sides
Video Sync	EIA–RS–170A Compliant Black Burst Sync

Notes:

(1) Or any video/data format compatible with PFM characteristics as indicated in this Table.

(2) With the emphasis enabled the above set-up results in PFM frequencies of 53.27 MHz for the white level (100 IRE/714 mV), 48.57 MHz for the blanking level (0 IRE/0mv), and 46.67 MHz for sync tip (–40 IRE/–286 mV).

Notes:

1. Or any video/data format compatible with PFM characteristics as indicated in Table XXVIII.
2. With the emphasis enabled the above setup results in PFM frequencies of 53.27 MHz for the white level (100 Institute of Radio Engineers (IRE)/714 mV), 48.57 MHz for the blanking level (0 IRE/0 mv), and 46.67 MHz for sync tip (-40 IRE/-286 mV).

3.4.1.1.9.3 FIR NTSC PFM video transmitted optical power.

The FIR shall be designed to transmit a video PFM signal at an average optical power greater than –15.5 dBm.

3.4.1.1.9.4 Fiber optic cable characteristics.

The video/data and sync signals shall use fiber optic cable in accordance with Table XXIX.

Table XXIX. PFM NTSC video optical fiber characteristics.

Parameter	Dim.	Medium Characteristics
Operating Wave length (min/max)	nm	1270/1380
Fibre Type	–	graded index, multimode
Fibre Core Diameter (min/max)	µm	98/102
Fibre Cladding Diameter (min/max)	µm	138/142
Numerical Aperture (min/max)	–	0.28/0.32
Attenuation @ 1290± 10nm	dB/Km	≤ 4
Modal Bandwidth @ 1290± 10nm	MHz × Km	200
–Signal Timing:		
Optical Rise Time (10% to 90%)	ns	≤ 3.5
Optical Fall Time (10% to 90%)	ns	≤ 3.5
Random Jitter (peak to peak) (1)	ns	≤ 0.76
Data Dependent Jitter (peak to peak) (1)	ns	≤ 0.6
Duty Cycle Distortion (peak to peak) (1)	ns	≤ 1

Note:
(1) These parameter refer to fibre optic data test setup.

3.4.1.1.9.5 PFM NSTC video fiber optic cable bend radius.

The FIR shall develop the routing, installation, and handling procedures to assure the minimum bend radius of 2 in. or greater is maintained at all times for the fiber optic cable.

3.4.2 Flexibility and expansion.

a. The FIR software shall be modifiable via the ISS communication network.
b. FIR software shall be modularized separate from PI-specific hardware.
c. FIR software shall be written in C++ and/or Java programming languages with the exception of COTS software and software classified as time critical.
d. After deployment of the SAR, the FIR shall have the capability to transfer internal bus controller (Master) functions from the primary processor to at least one other processor.
e. Prior to SAR deployment, each computer communication bus (1553, Ethernet, etc.) shall be designed such that the transfer of all data from the basis experiments, as specified in FCF-DOC-002 and all associated FIR health data does not exceed 55% of bus bandwidth over any 10 second period.
f. After SAR deployment, each computer communication bus (1553, Ethernet, etc.) shall be designed such that all the transfer rates of all data from the basis experiments as specified in FCF-DOC-002, and all associated FIR health data does not exceed 60% of the bus bandwidth over any 10 second period.

g. Prior to the deployment of the SAR, during all planned operational modes, all single board computers and associated circuit boards in the FIR and the FIR shall be designed to have their volatile memory (e.g., RAM) sized such that the basic software functions required to perform the basis experiments and collect generated data as specified in FCF-DOC-002, do not utilize more than 55 percent of the bytes available for the particular volatile memory.
h. After SAR deployment, during all planned operational modes, all single board computers and associated circuit boards in the FIR shall be designed to have their volatile memory (e.g., RAM) sized such that the basic software functions required to perform the basis experiments and collect all generated data as specified in FCF-DOC-002 do not utilize more than 65 percent of the bytes available for the particular volatile memory.
i. Prior to the deployment of the SAR, during all planned operational modes, all single board computers and associated circuit boards in the FIR and the FIR shall be designed to have their non-volatile memory sized such that the basic software functions required to perform the basis experiments and collect generated data as specified in FCF-DOC-002, do not utilize more than 50 percent of the bytes available for the particular non-volatile memory.
j. After SAR deployment, during all planned operational modes, all single board computers and associated circuit boards in the FIR shall be designed to have their non-volatile memory sized such that the basic software functions required to perform the basis experiments and collect all generated data as specified in FCF-DOC-002 do not utilized no more than 80 percent of the bytes available for the particular non-volatile memory.
k. Prior to the deployment of the SAR, during all planned operational modes, all mass storage in the FIR and the FIR shall be sized such that the space required to store all data does not exceed 50 percent of the bytes available and 70 percent of the data read/write rates available as specified in the basis experiments in FCF-DOC-002, for the particular mass storage. To meet this requirement it shall be assumed that no data can be offloaded from the mass storage during the conduct of the experiment (i.e., all information generated and sent to the mass storage must be retained.).
l. After SAR deployment, during all planned operational modes, all mass storage in the FIR shall be sized such that the space required to store all data does not exceed 80 percent of the bytes available or 70 percent of the data read/write rates available as specified in the basis experiments in FCF-DOC-002, for the particular mass storage. To meet this requirement it shall be assumed that no data can be offloaded from the mass storage during the conduct of the experiment (i.e., all information generated and sent to the mass storage must be retained.)

3.4.3 Software portability.

a. The FIR software shall be designed to facilitate migration for programs from systems supporting FIR development.
b. FIR software shall be designed to facilitate migration of programs to upgraded hardware and firmware.

3.4.4 Data date/time stamps.

a. All data shall be date/time stamped as specified in paragraph 3.2.1.35 by the primary computer collecting the data.

b. Data flowing from one computer to another where date/time stamps have been applied shall not have their date/time stamps overwritten.

3.5 Logistics.

3.5.1 Maintenance.

The FIR shall be designed to allow for changeout, maintenance, and upgrade of hardware and software to conduct the basis experiments as specified in FCF-DOC-002.

3.5.2 Supply.

The FIR shall be designed to perform a minimum of 5 basis-type experiments per year as specified in FCF-DOC-002 using no more than the up-mass and stowage volume resupply requirements as specified in paragraph 3.2.2.

3.5.3 Facilities and facility equipment.

Facilities and facility equipment are described in FCF-SPEC-0005.

3.6 Personnel and training.

3.6.1 Personnel.

a. The FIR shall be designed to be nominally maintained and operated by one crew member.
b. The FIR shall be designed to be operated using ground commands once experiment setup is completed by the crew.
c. The FIR shall be designed such that no more than two crew members are required for off-nominal and troubleshooting operations.

3.6.2 Training.

The FIR shall be designed for simple and logical installation, maintenance, and operation to minimize crew training. Details concerning training are provided in FCF-DOC-0005.

3.7 Major component characteristics.

The FIR assemblies listed in paragraphs 3.1.6 and 3.1.9 have their individual product specification which lists their specific requirements. Certain assemblies shall meet the additional requirements listed in the following paragraphs.

3.7.1 Water Thermal Control System (WTCS).

a. Coolant contained in the WTCS that interfaces with ISS US Lab ITCS coolant shall satisfy the cleanliness and materials requirements specified below:
   1. The WTCS shall use fluids that meet the requirements specified in SSP 30573.
   2. The WTCS shall meet the fluid system cleanliness levels specified in SSP 30573.

   The WTCS shall use internal materials that are compatible according to MSFC-SPEC-250, Table III or that will not create a potential greater than 0.25 V with the ISS system internal materials due to a dissimilar metal couple.
b. The WTCS shall be delivered on orbit and during transport charged with coolant as specified in paragraph 3.7.1 a. Integrated racks that are not actively serviced by the MPLM Thermal Control System during transport shall be charged to allow for thermal expansion between the temperatures of 1.67 and 46°C (35 and 114.8°F).
c. The WTCS shall be designed to meet the US Lab moderate temperature loop pressure drop specified in Figure 58 with both halves of each mated quick disconnect (QD) pair included as part of the payload pressure differential.
d. The WTCS shall be designed to meet the US Lab moderate temperature loop allowable flow rate: ITCS Selectable Coolant Flow Rate = 100 – 745 lbm/hr (45 – 339 kg/hr)
e. The WTCS shall be designed to meet the US Lab moderate temperature loop coolant supply temperature: ITCS Coolant Supply Temperature = 61 – 65 ^{o}F (16 – 18.3 ^{o}C)
f.
   1. The WTCS using moderate temperature coolant at operating modes above 1025 W shall have a minimum differential temperature across the integrated rack (inlet to outlet) of 19.5°C (35°F).
   2. The WTCS using moderate temperature coolant shall be designed to operate using 100 lbm/hr flow during operating modes which require less than 1025 W of power.
   3. The maximum moderate temperature coolant return temperature shall be no greater than 49°C (120°F).
g. The WTCS shall withstand the moderate temperature loop maximum design pressure of 121 psia (834 kPa).
h. The WTCS shall assess the payload equipment and rack internal water loop piping to ensure that it is fail safe in the case of loss of cooling under all modes of operation.
i. The WTCS shall not exceed the maximum rack leakage rate of water of 14x10 –3 scc/ hr (liquid) per each thermal loop at the MDP of 121 psia (834 kPa).
j. WTCS QD's shall not exceed the maximum air inclusion of .30 cc maximum per mate or demate operation.
k. The WTCS automated flow control systems shall be designed such that set point changes resulting in flow rate changes greater than 5 lbm/hr shall take at least 100 s to reach 63.2% (i.e., $1 - e^{-1}$) of the commanded change in flow rate.
l. The WTCS shall contain no more than the maximum allowable coolant quantity of water, referenced at 61°C (141.8°F). The maximum allowable coolant quantity of water in the US Lab MTL is 42.25 gal. (159.9 L).

   Note: Payload racks are to have a design target for total rack coolant volume of no more than 1.82 gal (6.90 L) on the MTL.

m. The WTCS shall not exceed the maximum allowable gas inclusion or volume at the maximum design pressure into the US Lab Internal Thermal Control System of 8.88 in^3 (0.146 L).
n. The WTCS shall meet the physical and functional interfaces depicted in Figure 1 of the FSS Interface Definition Drawing (IDD), 683-17103.

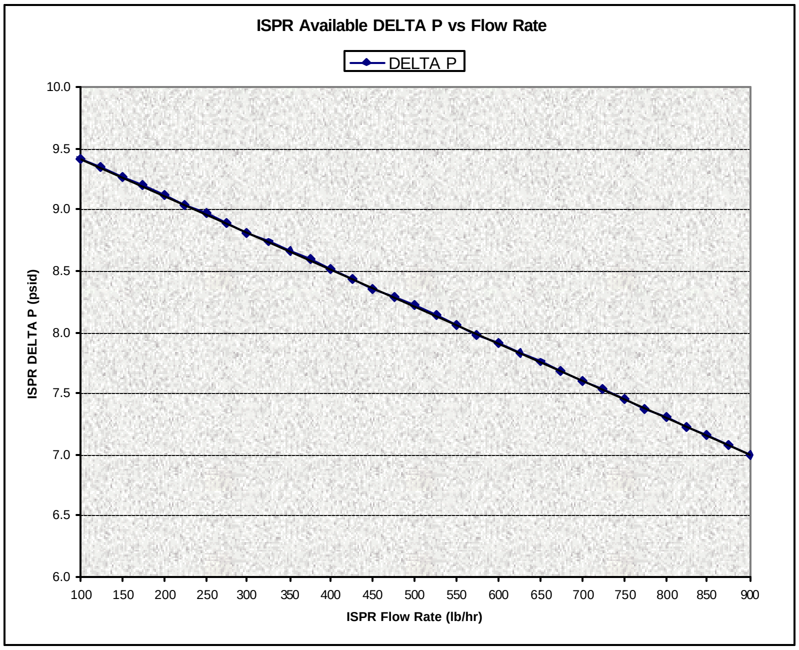


Figure 58. U.S.Lab MTL available pressure drop vs. flow rate

3.7.2 Vacuum exhaust system/waste gas system(VES/WGS) requirements.

a. The FIR shall limit its vented exhaust gas to a pressure of 276 kPa (40 psia) or less at the rack to ISS interface.
b. The FIR volume connected to the VES/WGS shall be designed to a maximum design pressure of at least 276 kPa (40 psia) with safety factors in accordance with SSP 52005, paragraph 5.1.3.
c. The FIR shall be two failure tolerant to protect against failure conditions which would exceed VES/WGS max design pressure of 40 psia.
d. The initial temperature range of exhaust gases shall be between 16 and 45°C (60 and 113°F).
e. The initial dewpoint of exhaust gases shall be limited to 16°C (60°F) or less.
f. The FIR exhaust gases vented into the VES/WGS of the US Lab shall be compatible with the wetted surface materials of the respective laboratory(ies) in which the integrated rack will operate, as defined in SSP 41002, paragraph 3.3.7.2. (See Appendix H for exceptions to this requirement.)
g. The FIR shall be nonreactive with other vent gas mixture constituents.

h. The FIR shall provide a means of removing gases that would adhere to the ISS VES/WGS tubing walls at a wall temperature of 4°C (40°F) and at a pressure of 10 (-3) torr.
i. The FIR shall remove particulates from vent gases that are larger than 100 µm in size.
j. Gases venting from the FIR shall be in accordance with the list of acceptable exhaust gases with verified compatibility to the USL VES wetted materials as specified in SSP 57000 Appendix D1 and the list of unacceptable gases that are not compatible with the USL VES as specified in Appendix D2.
k. Exhaust gases shall be compatible with paragraph 3.4 of SSP 30426 for molecular column density, particulates, and deposition on external ISS surfaces.
l. The FIR shall provide containment, storage, and transport hardware for gases that are incompatible with the vacuum exhaust or external environment.
m. Containment hardware for incompatible exhaust gases shall meet the redundant container requirements specified in NSTS 1700.7 ISS Addendum, paragraph 209.1 b.

3.7.3 ISS nitrogen usage requirements.

a. The FIR shall provide a means, located within the integrated rack envelope, to turn on and off the flow of nitrogen to the integrated rack and to control the flow of nitrogen to not exceed 5.43 kg/hr (12 lbm/hr) when connected to the nitrogen interface operating pressure range of 517 to 827 kPa (75 to 120 psia).
b. The MDP of the FIR interfacing with the nitrogen system shall be 1,379 kPa (200 psia).
c. The FIR nitrogen system shall be designed for a nitrogen supply temperature range of 15.6 to 45°C (60 to 113°F).
d. The FIR shall have a nitrogen leakage rate no greater than 10 –3 scc/s.

3.7.4 Vacuum resource system/vacuum vent system((VRS/VVS) requirements.

a. FIR shall limit its vented VRS/VVS gases to a pressure of 10^{-3} torr or less at the rack to Station interface.
b. The FIR volume connected to the VRS/VVS shall be designed to a maximum design pressure of at least 276 kPa (40 psia) with safety factors in accordance with SSP 52005 paragraph 5.1.3.
c. The FIR shall be two failure tolerant to protect against failure conditions which would exceed VRS/VVS max design pressure of 40 psia.
d. FIR shall limit its gas throughput to the VRS/VVS to less than 1.2×10^{-3} torr liters/second.
e. Vented VRS/VVS gases shall be in accordance with the list of acceptable exhaust gases with verified compatibility to the USL VES wetted materials as specified in SSP 57000 Appendix D1 and the list of unacceptable gases that are not compatible with the USL VES as specified in Appendix D2.

3.8 Precedence.

All specifications, standards, exhibits, drawings, or other documents that are referenced in this specification are hereby incorporated as cited, with the exception of those documents specifically cited to be used for reference only.

4 QUALITY ASSURANCE

Verification of the FIR shall be performed as specified in the FIR Payload Verfication Plan (FIR-PLN-0147). Verifications shall show compliance with each “shall” statement in sections 3 and 5. Non “shall” statements are not required to be verified for compliance.

4.1 General.

The primary location for FIR verification will be at the contractor test facility or at locations contracted to perform verifications by the contractor. Data and reports generated as part of the verification process will be retained for the life of the FIR. The FIR verification will be conducted through inspection, analysis, demonstration, and test.

The following verification methods are defined and shall be used to qualify the system:

1. Inspection – Verification by visual examination of the item, or reviewing descriptive documentation, and comparing the appropriate characteristics with predetermined standards to determine conformance to requirements without the use of special laboratory equipment or procedures.
2. Analysis – Verification by technical or mathematical models or simulation, algorithms, charts, graphs, or circuit diagrams, and representative data.
3. Demonstration – Verification by operation, adjustment or reconfiguration of items performing their designed functions under specific scenarios. The items may be instrumented and quantitative limits or performance monitored, but only check sheets rather than actual performance data are required to be recorded.
4. Test – Verification through systematic exercising of the item under all appropriated conditions. Performance is quantitatively measured either during or after the controlled application of either real or simulated functional or environmental stimuli. The analysis of data derived from a test is an integral part of the test and may involve automated data reduction to produce the necessary results.

The verification program is an incremental process that is a companion to the assembly process. Component level requirements are verified first, followed by assembly level verification, to the system level verification. Requirements in this specification may have been verified at lower levels. Inspection of data from lower level component and assembly verifications will be used to verify appropriate requirements in this specification.

4.1.1 Responsibility for verifications.

Unless otherwise specified in the contract, the contractor is responsible for the performance of all verification requirements as specified herein. Except as otherwise specified in the contract, the contractor may use any facility suitable for the performance of the verification requirements specified herein, unless disapproved by the government. The government reserves the right to perform any of the verifications set forth in this specification.

4.1.2 Special tests and examinations.

All test measurement equipment and standards used in performance of the verifications specified herein shall have their calibration data traceable to NIST measurement standards.

4.2 Verification requirements.

All verification tests shall be performed using the preproduction sample as specified in *FIR Critical Item Product Specification*. The sample shall be modified to the extent necessary to conduct testing. All FIR hardware/software deviating from the preproduction sample shall be documented. Written approval from the government quality assurance representative or the government quality assurance designee to proceed with the verification test using FIR hardware/software that deviates from the preproduction sample shall be obtained before beginning the verification test. Detailed verification requirements for the FIR are specified in FIR-PLN-0147.

4.3 Precedence.

All specifications, standards, exhibits, drawings, or other documents that are referenced in this specification are hereby incorporated as cited, with the exception of those documents specifically cited to be used for reference only.

4.4 Requirement/verification cross-reference.

The requirement/verification cross-reference is located in APPENDIX F.

5 PREPARATION FOR DELIVERY

This section gives the requirements for the preservation, packing, marking, and labeling of the FIR and its associated flight hardware for shipment to the launch site.

5.1 Preservation.

Not applicable.

5.2 Packing.

Packaging, handling, and transportation shall be in accordance with NHB 6000.1

5.2.1 Launch configured FIR.

The FIR in its launch configuration, including stowage items required to complete the on-orbit configuration, shall be considered as Class I as specified in NHB 6000.1.

5.2.1.1 Cleanliness.

All surfaces of all hardware shall be cleaned to the VC – S cleanliness level as specified in SN-C-0005, except for those surfaces that are covered to maintain cleanliness for oxygen usage.

5.2.1.2 Procedures.

All flight hardware shall be packed according to its specific packing procedures in the designated containers.

5.2.2 Flight spares and other equipment.

Spares and all other FIR equipment shall be considered as Class III or higher as specified in NHB 6000.1.

5.3 Marking and labeling.

Not applicable.

5.4 Marking for shipment.

Marking of packaging containing pressurized gases and chemicals shall be in accordance with Department of Transportation regulations.

6 NOTES

There are no notes at this time.

APPENDIX A ACRONYMS

A.1 Scope.

This appendix lists the acronyms used in this document.

A.2 Acronyms List.

A	amperes
A_I	inherent availability
ac	alternating current
APID	application process identification
APM	Attached Pressurized Module
ARIS	Active Rack Isolation System
ATCA	Air Thermal Control Assembly
ATCS	Air Thermal Control System
atm	atmospheres
AWG	average wire gauge
BIT	built-in-test
C	centigrade, Celsius
cc	cubic centimeter
CCS	Calendar Segmented Time Code
CCSDS	Consultative Committee for Space Data Systems
CIR	Combustion Integrated Rack
CFU/m^3	Colony Forming Units/cubic meter
cm	centimeter
COF	Columbus Orbital Facility
COTS	commercial-off-the-shelf
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
CUC	Unsegmented Time Code
C&W	caution and warning
dB	decibels
dBA	acoustic decibel level
dBm	decibels referenced to 1 mW
dc	direct current
deg	degrees
DOORS	Dynamic Object Oriented Requirements System
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EPCE	Electrical Power Consuming Equipment
EPCU	Electrical Power Control Unit
EPS	Electrical Power System
equiv.	Equivalent
ESA	European Space Agency
ESD	electrostatic discharge
F	Fahrenheit

fc	foot-candles
FCF	Fluids and Combustion Facility
FCU	FOMA Control Unit
FEM	finite element modeling
FIR	Fluids Integrated Rack
FOMA	Fuel/Oxidizer Management Assembly
ft	feet
g	gravity
g^2/Hz	gravity squared/Hertz
GC	Gas Chromatograph
GFCI	Ground Fault Circuit Interrupters
GN2	gaseous nitrogen
GRC	Glenn Research Center
grms	gravity-root mean square
GSE	Ground Support Equipment
H	Halt symbol
HRDL	high rate data link
HFR	high frame rate
HiBMs	High Bit Depth/Multi-spectral
HR	high resolution
HRFM	high-rate frame multiplexer
Hz	Hertz
ICD	Interface Control Document
IDD	Interface Definition Document
IEEE	Institute of Electrical and Electronic Engineers
in.	inches
in-lb	inch-pounds
IOP	Input/Output Package
IPP	Image Processing Package
IR	infrared
IRD	Interface Requirements Document
IRE	Institute of Radio Engineers
ISPR	International Standard Payload Rack
ISS	International Space Station
ITCS	Internal Thermal Control System
IVA	Intravehicular Activity
IVS	Internal Video Subsystem
J	joules
JSC	Johnson Space Center
K	Kelvin
kg	kilograms
kg/hr	kilograms per hour
KSC	Kennedy Space Center
kPa	kilopascals
LAN	local area network
lbs	pounds

lbf	pounds force
lbm	pounds per minute
LED	Light Emitting Diode
LISN	Line Impedance Simulation Network
LRDL	low rate data link
LSB	Least Significant Bit
M	meter
mA	milliampere
Mbits	megabits
Mbps	megabytes per second
MDM	Multiplexer-Demultiplexer
MDP	Maximum Design Pressure
MHz	megahertz
mm	millimeter
MMCH/Y	mean maintenance crew hours per year
mod.	Modification
mph	miles per hour
MPLM	Multi-Purpose Logistics Module
MRDL	medium rate data link
MRPO	Microgravity Research Program Office
ms	millisecond
m/s	meter/second
msec	millisecond
MSFC	Marshall Space Flight Center
MTBM	mean time between failures
MDT	mean delay time
MTTF	mean time to failure
MTTR	mean time to repair
N	Newton
N_2	nitrogen
N/A	Not applicable
NASDA	National Space Development Agency of Japan
NIRA	Non-Isolated Rack Assessment
nF	nanofarad
NIST	National Institute of Standards and Technology
nm	nanometer
N-m	Newton-meter
NRZI	Non Return to Zero Event
ns	nanosecond
NTSC	National Television Systems Committee
NVR	No verification required
O_2	oxygen
ORU	Orbital Replacement Unit
oz	ounces
Pa	Pascals
PCS	Portable Computer System

PFE	Portable Fire Extinguisher
PFM	Pulse Frequency Modulation
pf/m	picofarad per meter
PI	Principal Investigator
PIN	Part Identification Number
PDRP	Payload Display Review Panel
PRCU	Payload Rack Checkout Unit
psi	pounds per square inch
psia	pounds per square inch absolute
PSRP	Payload Safety Review Panel
PUL	Portable Utility Light
PVP	Payload Verification Plan
QD	quick disconnect
ref.	Reference
rev.	revision
RH	relative humidity
RHA	Rack Handling Adapters
RMSA	Rack Maintenance Switch Assembly
RPC	Remote Power Controller
RPCM	Remote Control Power Module
RT	Remote Terminal
RUP	Rack Utility Panel
SAMS	Spacecraft Acceleration Measurement System
SAR	Shared Accommodations Rack
scc	standard cubic centimeter
SD	standard deviation
sec	second
SEE	single event effect
SMAC	Spacecraft Maximum Acceptable Concentration
SPL	sound pressure level
SRD	Science Requirements Document
SSC	Station Support Computer
STEP	Suitcase Test Environment for Payloads
TBC	To be confirmed
TBD	To be determined
TBE	Teledyne Brown Engineering
TCS	Thermal Control System
temp.	temperature
UIP	Utility Interface Panel
UOP	Utility Outlet Panel
US Lab	United States Laboratory Module
UV	ultraviolet
VC – S	Visibly Clean – Sensitive
Vdc	voltage direct current
VES/WGS	Vacuum Exhaust System/Waste Gas System
VRS/VVS	Vacuum Resource System/Vacuum Vent System

Vrms	voltage root mean square
W	watts
WFCA	Water Flow Control Valve
WTCS	Water Thermal Control System
µA	microampere
µg	microgravity
µsec	microsecond
03. .	ohm

APPENDIX B DEFINITIONS

B.1 Scope.

This section defines special terminology used in this document.

B.2 Definitions.

Access port: Hole that allows penetration of the Portable Fire Extinguisher nozzle.

Adjunct Active Portable Equipment: Equipment operated outside the rack required to support nominal payload operations (including any required GFE).

Acoustic reference: All sound pressure levels in decibels are referenced to 20 μPa.

Active air exchange: Forced convection between two volumes. For example, forced convection between a subrack payload and the internal volume of an integrated rack, or forced convection between a subrack payload and the cabin air.

Alignment marks: Straight or curved lines of sufficient length and width to allow alignment; applied to both mating parts. Align when the parts are in the installation position, and are visible during alignment and attachment.

Amu (One Atomic Mass Unit): Equal to one-twelfth the mass of a carbon-12 atom; tile average atomic mass is called the atomic weight.

Applicable PI hardware/software: Hardware/software provided by the PI experiment required to perform a NASA Research Announcement experiment in the FIR.

Boss: Protruding hard-points for GSE attachment.

Brightness ratio: The ratio of the maximum light level on the work surface area to the minimum light level on the work surface area.

Catastrophic hazard: Any hazard which causes loss of on-orbit life sustaining system function.

Common Mode Noise: Refer to SSP 30482.

Commonality: Identical in form, fit, and function.

Continuous Noise Source: A significant noise source which exists for a cumulative total of 8 hours or more in any 24-hour period.

Critical hazard: Any hazard which may cause a non-disabling injury, severe occupational illness, loss of emergency procedures, or major damage to one of the following: the launch or servicing vehicle, manned base, an on-orbit life sustaining function, a ground facility, or any critical support facility.

Current limiting: The current is limited to a specific level plus or minus a percentage for tolerance.

Detergent wipes: Detergent-saturated tissues used for interior surfaces and window cleaning.

Disinfecting wipes: Tissue saturated with a disinfecting cleansing agent or agents for cleanup of biological spills and biologically contaminated surfaces.

Dry wipes: Utility wipes used for compartment and equipment cleaning and spill clean-up.

Electromagnetic compatibility (EMC): The capability of systems and all associated subsystems/equipment to perform within design limits without degradation due to the Electromagnetic Effect encountered during accomplishment of the assigned mission. The deliverable end item compatibility test is as described in paragraph 3.6.2 of SSP 30243.

Electromagnetic interference (EMI): Any electromagnetic disturbance, phenomenon, signal, or emission (man-made or natural) which causes equipment performance outside of the equipment's design limits. Testing is described in SSP 30237 and SSP 30238, as referenced by SSP 57000, paragraph 3.2.4.4.

emergency condition: Toxic atmosphere, rapid cabin depressurization, or fire.

EPCE: Equipment that consumes electrical power including battery powered equipment.

Fire event: Localized or propagating combustion, pyrolysis, smoldering, or other thermal degradation process characterized by the potentially hazardous release of energy, particulates, or gasses.

GSE Plane: A reference plane that is defined by the front surface of the four rack GSE bosses.

Hazard: The presence of a potential risk situation caused by an unsafe act or condition.

Health and status data: Information originating at the payload and passed to the respective payload MDM that provides the crew and the ground confirmation of payload performance, operational state, resource consumption, and assurance that the payload is operating within the safety guidelines as defined by the Payload Safety Review Panel and the ISS Flight Rules. Some examples of payload health and status data are subsystem status (power, voltages, currents, temperatures, pressures, fluid flow velocities, warning indicators, error messages/codes, etc.), digital communications system statistics (1553, Ethernet, and high rate system status, etc.), and video system status (camera and video recorder on/off indications, synchronization indicators, etc.).

integrated rack: The ISPR and all other subrack equipment which operates within a rack.

Intermittent Noise Source: A significant noise source which exists for a cumulative total of less than 8 hours in a 24-hour period.

Line Impedance Stabilization Network: An electrical circuit, including resistance, capacitance, and inductance, used to simulate a specific electrical power bus.

Maintenance: The scheduled or unscheduled activity (inspections, preventive and corrective actions, restorations, replacement of assemblies and components, and resupply operations) intended to keep the proper functioning of FIR hardware and software.

Maintenance item: Any assembly or component designed to be replaceable on orbit to maintain the proper functioning of FIR hardware.

Mils: Length measurement equal to 0.001 in.

non-normal: Pertaining to performance of the Electrical Power System outside the nominal design due to ISS system equipment failure, fault clearing, or overload conditions.

On-Orbit Momentary Protrusions: Payload obstructions which typically would protrude for a very short time or could be readily eliminated by the crew at any time. Momentary protrusions include only the following: drawer/door/cover replacement or closure.

On-Orbit Permanent Protrusion: A payload hardware item which is not ever intended to be removed.

On-Orbit Protrusions for Keep Alive Payloads: A protrusion which supports and/or provides the uninterrupted resources necessary to run an experiment. On-orbit protrusions for Keep Alive Payloads includes only power/data cables and thermal hoses.

On-Orbit Semi-Permanent Protrusion: A payload hardware item which is typically left in place but can be removed by the crew with hand operations or standard IVA tools.

Example: SIR and ISIS drawer handles, other equipment that does not interfere with crew restraints and mobility aids.

On-Orbit Temporary Protrusion: A payload item which is typically located in the aisle for experiment purposes only. These items should be returned to their stowed configuration when not being used.

Example: Front panel mounted equipment.

Operate: Perform intended design functions given specified conditions.

Orbital Replacement Unit: Any unit mounted to the exterior of an assembly that can be removed and replaced with an identical unit while on orbit. Items internal to hardware, such as electronic circuit boards and internal disk drives, are not considered ORU's.

out-of-tolerance: Any condition outside of normal or specified operational limits.

Potential fire source: Any electrical, chemical, or other energy source capable of creating a fire event (e.g., electrically powered equipment).

Protrusion: A payload hardware item which extends beyond the GSE plane.

Rack equivalent: The volume equal to the total internal volume of one empty ISPR.

Reusable wipes: Utility handwipes that can be impregnated or dampened with premixed evaporative detergent/biocidal solutions or with water.

Safety-critical: Having the potential to be hazardous to the safety of hardware, software, and personnel.

Specularity: The ratio of the flux leaving a surface or medium by regular (specular) reflection to the incident flux.

Standard conditions: Measured volumes of gasses are generally recalculated to 0°C temperature and 760 mm Hg pressure, which have been arbitrarily chosen as standard conditions.

Training: To educate people in the design, operation, maintenance, and troubleshooting aspects of the FIR.

Up-mass: The mass of equipment to be transported from the ground to the ISS.

Up-volume: The volume of equipment to be transported from the ground to the ISS.

Vented conditions: Condition (temperature and pressure) of the gas in the experiment chamber as the chamber is opened to the ISS VES/VGS.

VES/WGS: Vacuum Exhaust System and/or Waste Gas System. The USL, JEM, and APM each have similar systems to vent gases to space from an experiment chamber. The system in the USL is the Vacuum Exhaust System and the systems in the JEM and APM are the Waste Gas Systems.

VRS/VVS: Vacuum Resource System and/or Vacuum Vent System. The USL, JEM, and APM each have similar systems to carry leakage gases and offgassed gases away from the experiment chamber to maintain vacuum. The system in the USL is the Vacuum Resource System and the systems in the JEM and APM are the Vacuum Vent Systems.

Wire derating: Wire is derated based on the current flow, environment, and electrical circuitry that operates within an integrated rack or within Electrical Power Consuming Equipment individual boxes.

APPENDIX C FIR INTERNAL PHYSICAL INTERFACES

C.1 Scope.

This section gives the FIR internal physical interfaces.

C.2 FIR internal physical interfaces.

The FIR internal physical interfaces are given below. See the respective product specifications for detailed interface description.

C.2.1 ISPR to FIR attachment interface.

a. ATCU to Rack Attachment Bracket
b. Optics Bench to Rack Attachment Bracket
c. EPCU Bracket to Rack Attachment Bracket
d. IOP Bracket to Rack Attachment Bracket
e. Center Post to Rack Attachment Bracket
f. Optics Bench Slide to Rack Attachment Bracket
g. GIS to Rack Attachment Bracket
h. Smoke Detector to Rack Attachment Bracket
i. WTCS to Rack Attachment Bracket

C.2.2 FIR component to optics bench attachment.

a. High Resolution Camera Assembly
b. Color Camera Assembly
c. Ultra-High Frame Rate Camera Assembly
d. White Light Assembly
e. Nd: YAG Laser Assembly
f. Laser Diodes Assembly
g. Fluids Science Avionics Package Assembly
h. PI Fluids Science Avionics Package Assembly
i. High Resolution Image Acquisition Assembly
j. Color Image Acquisition Assembly
k. High Magnification Lens Assembly
l. Macroscopic Lens Assembly #1
m. Macroscopic Lens Assembly #2
n. Macroscopic Lens Assembly #3
o. Collimator Assembly
p. Scanning Mirror Assembly-
q. Translational Stage Assembly
r. Spot Cooling Fan Post Assembly
s. Mobile Camera Mounting Post Assembly
t. IPSU Assembly
u. SAMS Head

APPENDIX D FIR INTERNAL ELECTRICAL/DATA INTERFACES.

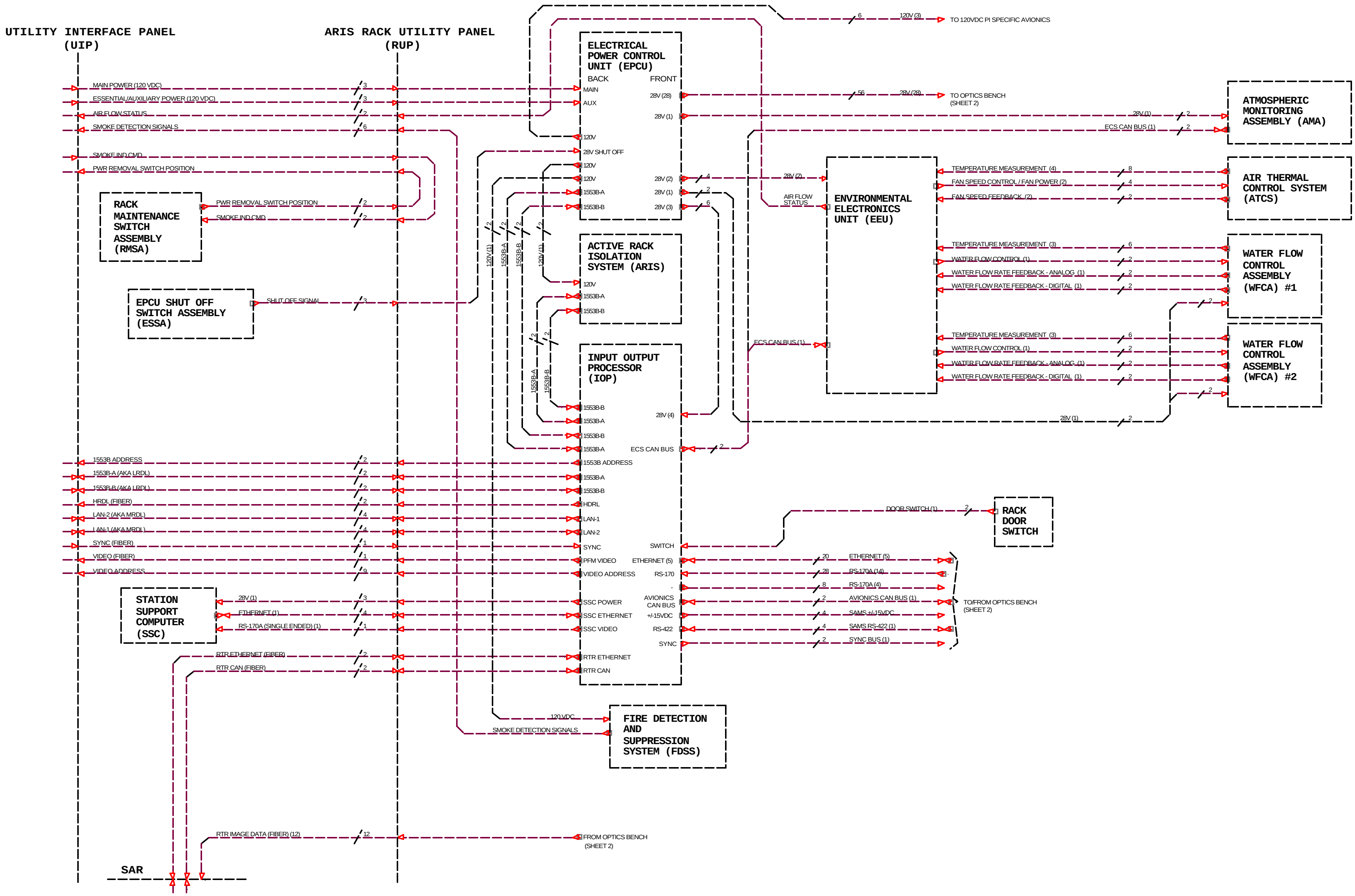
D.1 Scope.

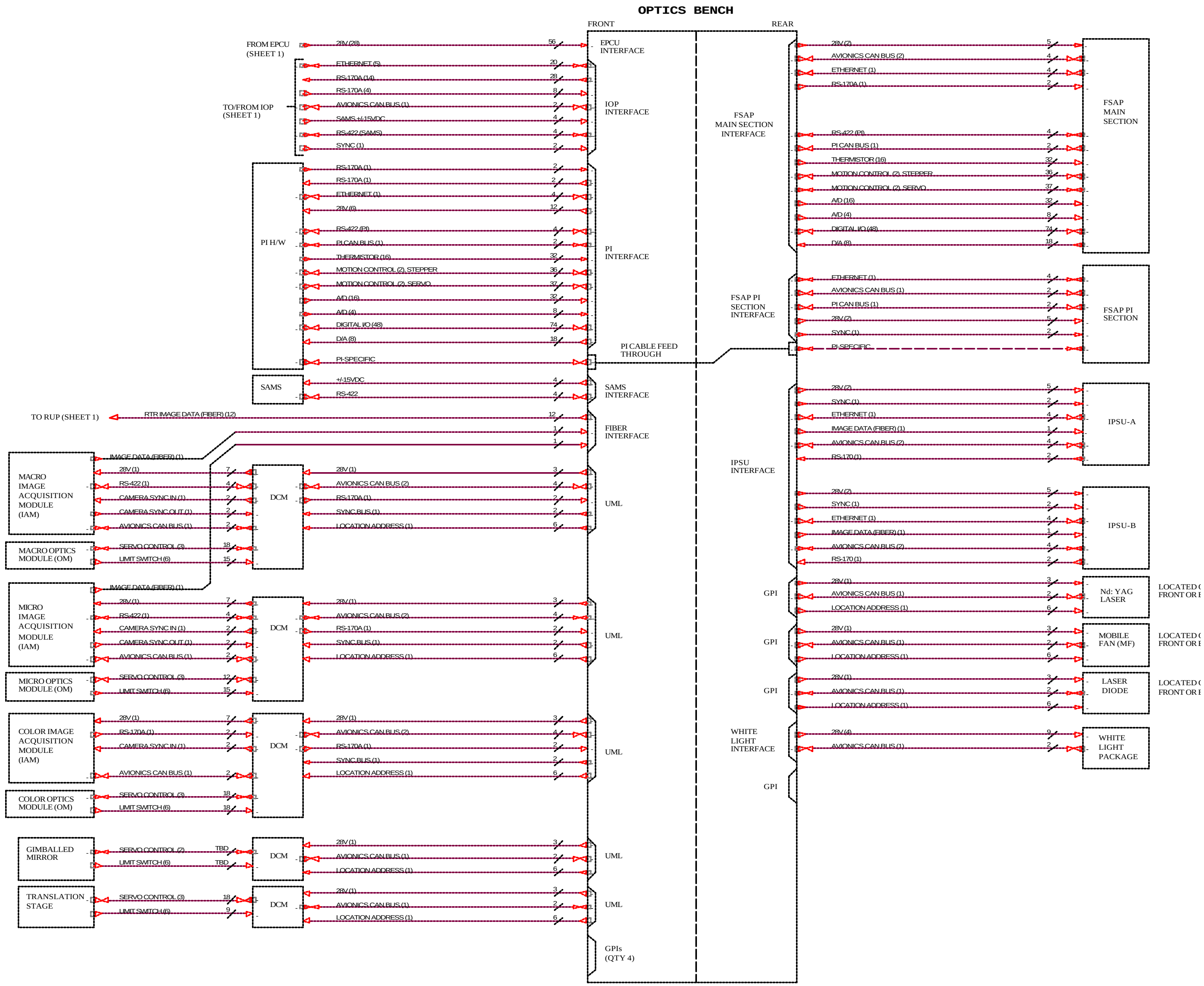
This section gives the FIR internal electrical/data interfaces.

D.2 FIR internal electrical/data interfaces.

The FIR internal electrical/data interfaces are given in Figure 59.

Figure 59. FIR internal electrical/data interfaces


UTILITY INTERFACE PANEL (UIP)
ARIS RACK UTILITY PANEL (RUP)
ELECTRICAL POWER CONTROL UNIT (EPCU)
BACK
FRONT
MAIN
AUX
120V
28V SHUT OFF
1553B-A
1553B-B
28V (28)
28V (1)
28V (2)
28V (3)
TO 120VDC PI SPECIFIC AVIONICS
TO OPTICS BENCH (SHEET 2)
MAIN POWER (120 VDC)
ESSENTIAL/AUXILIARY POWER (120 VDC)
AIR FLOW STATUS
SMOKE DETECTION SIGNALS
SMOKE IND CMD
PWR REMOVAL SWITCH POSITION
RACK MAINTENANCE SWITCH ASSEMBLY (RMSA)
EPCU SHUT OFF SWITCH ASSEMBLY (ESSA)
SHUT OFF SIGNAL
ACTIVE RACK ISOLATION SYSTEM (ARIS)
INPUT OUTPUT PROCESSOR (IOP)
28V (4)
ECS CAN BUS
1553B ADDRESS
1553B-A (AKA LRDL)
1553B-B (AKA LRDL)
HRDL (FIBER)
LAN-2 (AKA MRDL)
LAN-1 (AKA MRDL)
SYNC (FIBER)
VIDEO (FIBER)
VIDEO ADDRESS
HRDL
LAN-1
LAN-2
SYNC
PFM VIDEO
SWITCH
ETHERNET (5)
RS-170
AVIONICS CAN BUS
+/-15VDC
RS-422
SSC POWER
SSC ETHERNET
SSC VIDEO
RTR ETHERNET
RTR CAN
STATION SUPPORT COMPUTER (SSC)
28V (1)
ETHERNET (1)
RS-170A (SINGLE ENDED) (1)
RTR ETHERNET (FIBER)
RTR CAN (FIBER)
RTR IMAGE DATA (FIBER) (12)
FROM OPTICS BENCH (SHEET 2)
SAR
FIRE DETECTION AND SUPPRESSION SYSTEM (FDSS)
120 VDC
ENVIRONMENTAL ELECTRONICS UNIT (EEU)
AIR FLOW STATUS
ECS CAN BUS (1)
ATMOSPHERIC MONITORING ASSEMBLY (AMA)
AIR THERMAL CONTROL SYSTEM (ATCS)
TEMPERATURE MEASUREMENT (4)
FAN SPEED CONTROL / FAN POWER (2)
FAN SPEED FEEDBACK (2)
WATER FLOW CONTROL ASSEMBLY (WFCA) #1
WATER FLOW CONTROL ASSEMBLY (WFCA) #2
TEMPERATURE MEASUREMENT (3)
WATER FLOW CONTROL (1)
WATER FLOW RATE FEEDBACK - ANALOG (1)
WATER FLOW RATE FEEDBACK - DIGITAL (1)
RACK DOOR SWITCH
DOOR SWITCH (1)
RS-170A (14)
RS-170A (4)
AVIONICS CAN BUS (1)
SAMS +/-15VDC
SAMS RS-422 (1)
SYNC BUS (1)
TO/FROM OPTICS BENCH (SHEET 2)


OPTICS BENCH
FRONT
REAR
FROM EPCU (SHEET 1)
TO/FROM IOP (SHEET 1)
EPCU INTERFACE
IOP INTERFACE
PI INTERFACE
PI H/W
SAMS
SAMS INTERFACE
TO RUP (SHEET 1)
FIBER INTERFACE
PI CABLE FEED THROUGH
FSAP MAIN SECTION INTERFACE
FSAP PI SECTION INTERFACE
FSAP MAIN SECTION
FSAP PI SECTION
IPSU INTERFACE
IPSU-A
IPSU-B
MACRO IMAGE ACQUISITION MODULE (IAM)
MACRO OPTICS MODULE (OM)
MICRO IMAGE ACQUISITION MODULE (IAM)
MICRO OPTICS MODULE (OM)
COLOR IMAGE ACQUISITION MODULE (IAM)
COLOR OPTICS MODULE (OM)
GIMBALLED MIRROR
TRANSLATION STAGE
DCM
UML
GPI
GPIs (QTY 4)
Nd: YAG LASER
MOBILE FAN (MF)
LASER DIODE
WHITE LIGHT INTERFACE
WHITE LIGHT PACKAGE

APPENDIX E FIR INTERNAL ENVIRONMENTAL CONTROL SYSTEM INTERFACES

E.1 Scope.

This section gives the FIR internal environmental control system interfaces.

E.2 FIR internal environmental control system interfaces.

The FIR internal environmental control system interfaces are given in Table XXX.

Table XXX. FIR internal environmental control system interfaces

Interface	Connection	Fluid
WTCS to EPCU	Self-Sealing Fluid QD's, Power	Cool Water
WTCS to ATCU	Self-Sealing Fluid QD's	Cool Water
WTCS to ARIS Coldplate	Self-Sealing Fluid QD's	Cool Water
WTCS to Science	Self-Sealing QD's	Cool Water
GN2	Self-Sealing QD's	Nitrogen
VES	Self-Sealing QD's	Waste Gas
VRS	Self-Sealing QD's	Gas

APPENDIX F REQUIREMENT/VERIFICATION CROSS-REFERENCE.

F.1 Scope.

This section contains the requirement/verification cross-reference matrix.

F.2 Requirement/verification cross-reference.

Verification Method:	
NA – Not Applicable	NVR – No Verification Required
I – Inspection	A – Analysis
D – Demonstration	T – Test

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
Performance characteristics	3.2.1	4.1	I
Utilization	3.2.1.1	4.1.1	A
Minimum utilization	3.2.1.1.1	4.1.1.1	A
Additional utilization	3.2.1.1.2	4.1.1.2	A
Utilization capacity	3.2.1.1.3	4.1.1.3	A
Basis experiment capacity	3.2.1.1.3.1	4.1.1.3.1	A
Initial scheduled experiment capacity	3.2.1.1.3.2	4.1.1.3.2	TBD 03-03
FIR fluid physics science volume.	3.2.1.2 a	4.1.2	I and/or A
FIR fluid physics science volume.	3.2.1.2 b	4.1.2	I and/or A
Accommodate experiment test cells.	3.2.1.3	4.1.3	I and/or A
Acceleration and vibration requirement.	3.2.1.4	4.1.4	NVR
Provide microgravity environment.	3.2.1.4.1	4.1.4.1	A and/or T
Accommodate acceleration measurement device.	3.2.1.4.2a	4.1.4.2 a.	I
Accommodate acceleration measurement device.	3.2.1.4.2b	4.1.4.2 b.	A & T
Accommodate acceleration measurement device.	3.2.1.4.2c	4.1.4.2 c.	A & T
Accommodate acceleration measurement device.	3.2.1.4.2d	4.1.4.2 d.	A & T
Provide stable work volume temperature.	3.2.1.5	4.1.5	A & T
Maintain test cell temperature.	3.2.1.6	4.1.6	A & T
Control air circulation.	3.2.1.7a	4.1.7 a.	I, A & T
Control air circulation.	3.2.1.7b	4.1.7 b.	I, A & T
Contain optical elements.	3.2.1.8a	4.1.8 a.	A & T
Contain optical elements.	3.2.1.8b	4.1.8 b.	A & T
Contain optical elements.	3.2.1.8c	4.1.8 c.	NVR

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
Background lighting.	3.2.1.9	4.1.9	A & T
Background lighting intensity.	3.2.1.9.1a	4.1.9.1 a.	A & T
Background lighting intensity.	3.2.1.9.1b	4.1.9.1 b.	A & T
Background lighting intensity.	3.2.1.9.1c	4.1.9.1 c.	A & T
Background lighting intensity.	3.2.1.9.1d	4.1.9.1 d.	A & T
Background lighting field of view.	3.2.1.9.2a	4.1.9.2 a.	A & T
Background lighting field of view.	3.2.1.9.2b	4.1.9.2 b.	A & T
Laser light illumination.	3.2.1.10a	4.1.10 a.	A & T
Laser light illumination.	3.2.1.10b	4.1.10b	A & T
Laser light illumination.	3.2.1.10c	4.1.10c	A & T
Provide interface to ISS vacuum vent.	3.2.1.11	4.1.11	I & A
Provide on-orbit stowage.	3.2.1.12	4.1.12	I & A
Accommodate fluids test point quantity and duration.	3.2.1.13	4.1.13	A
Basis experiment imaging equipment.	3.2.1.14a	4.1.14 a.	A & T
Basis experiment imaging equipment.	3.2.1.14b	4.1.14 b.	A & T
PI-provided imaging equipment	3.2.1.14.1a	4.1.14.1 a.	TBD 07-02
PI-provided imaging equipment	3.2.1.14.1b	4.1.14.1 b.	TBD 07-02
Provide IR	3.2.1.14.2	4.1.14.2	I
Simultaneous imaging	3.2.1.15	4.1.15	I
Downlink images	3.2.1.16a	4.1.16 a.	A & T
Downlink images	3.2.1.16b	4.1.16 b.	A & T
Downlink images	3.2.1.16c	4.1.16 c.	A & T
Position fluids element imaging equipment.	3.2.1.17a	4.1.17 a.	A & T & D
Position fluids element imaging equipment.	3.2.1.17b	4.1.17 b.	D
PI imaging equipment positioning	3.2.1.18	4.1.18	A & T
Provide field of view	3.2.1.19	4.1.19	A
Provide resolution.	3.2.1.20	4.1.20	A
Particle speed vs. field of views.	3.2.1.21	4.1.21	A
Framing rate and recording duration.	3.2.1.22	4.1.22	A
Removable storage media.	3.2.1.23	4.1.23	NVR
Diagnostics	3.2.1.24	4.1.24	A
Temperature measurements.	3.2.1.25	4.1.25	I & A
Identify temperature measurement instrumentation.	3.2.1.26a	4.1.26 a.	I, A & T
Identify temperature measurement instrumentation.	3.2.1.26b	4.1.26 b.	I
Acquire and Store Pressure Data.	3.2.1.27 a	4.1.27	I, A & T
Ambient Pressure Measurement	3.2.1.27.1	4.1.27.1	I
Identify Pressure Measurement	3.2.1.28a	4.1.28 a.	I, A & T

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
Instrumentation.			
Identify Pressure Measurement Instrumentation.	3.2.1.28b	4.1.28 b.	I
Acquire and Store Force Data	3.2.1.29	4.1.29	I, A & T
Identify Force Measurement Instrumentation	3.2.1.30a	4.1.30 a.	I, A & T
Identify Force Measurement Instrumentation	3.2.1.30b	4.1.30 b.	I
Acquire and Store Voltage Data.	3.2.1.31	4.1.31	I, A & T
Identify voltage measurement instrumentation.	3.2.1.32a	4.1.32 a.	I, A & T
Identify voltage measurement instrumentation.	3.2.1.32b	4.1.32 b.	I
Acquire analog data.	3.2.1.33	4.1.33	A & T
Digital acquisition.	3.2.1.34	4.1.34	A & T
Data time stamps (relative to ISS timing signal)	3.2.1.35a	4.1.35 a.	A & T
Data time stamps (relative to ISS timing signal)	3.2.1.35b	4.1.35b	A & T
Data time stamps (ISS and FCF timing signal)	3.2.1.36a	4.1.36 a.	A & T
Data time stamps (ISS and FCF timing signal)	3.2.1.36b	4.1.36 b.	A & T
Data time stamps (ISS and FCF timing signal)	3.2.1.36c	4.1.36 c.	A & T
Analog output channels	3.2.1.37a	4.1.37 a.	I, A & T
Analog output channels	3.2.1.37b	4.1.37 b.	I, A & T
Analog output channels	3.2.1.37c	4.1.37 c.	I, A & T
Analog output channels	3.2.1.37d	4.1.37 d.	I, A & T
Internal/external triggering	3.2.1.38	4.1.38	A
Digital acquisition	3.2.1.39a	4.1.39 a.	I & A
Digital acquisition	3.2.1.39b	4.1.39 b.	I & A
Experiment-specific capabilities	3.2.1.40a	4.1.40 a.	A
Experiment-specific capabilities	3.2.1.40b	4.1.40 b.	A
Photon counters	3.2.1.40.1a	4.1.40.1a	I
Photon counters	3.2.1.40.1b	4.1.40.1b	I
Photon counters	3.2.1.40.1c	4.1.40.1c	I
Correlator	3.2.1.40.2a	4.1.40.2a	I
Correlator	3.2.1.40.2b	4.1.40.2b	I
Correlator	3.2.1.40.2c	4.1.40.2c	I
Correlator	3.2.1.40.2d	4.1.40.2d	I
Image analysis capability	3.2.1.41	4.1.41	A

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
On-orbit instrument calibration.	3.2.1.42	4.1.42	T
Replacement of on-orbit instruments.	3.2.1.42.1	4.1.42.1	D
Rack environment monitoring.	3.2.1.43	4.1.43	A & T
On-orbit data storage.	3.2.1.44	4.1.44	I
On-orbit data collection and transfer.	3.2.1.45	4.1.45	NVR
Processing and providing data.	3.2.1.45.1a	4.1.45.1 a.	I & T
Processing and providing data.	3.2.1.45.1b	4.1.45.1 b.	I & T
Processing and providing data.	3.2.1.45.1c	4.1.45.1 c.	T
Processing and providing data.	3.2.1.45.1d	4.1.45.1 d.	I & T
Processing and providing data.	3.2.1.45.1e	4.1.45.1 e.	T
Processing and providing data.	3.2.1.45.1f	4.1.45.1 f.	T
Processing and providing data.	3.2.1.45.1g	4.1.45.1 g.	T
On-orbit data transfer within FCF.	3.2.1.45.2	4.1.45.2	T
Use of fiber optics.	3.2.1.45.3	4.1.45.3	I
On-orbit data transfer to portable media.	3.2.1.45.4	4.1.45.4	I & T
FIR health status monitoring.	3.2.1.46	4.1.46	T
FIR/FCF health status monitoring.	3.2.1.46.1	4.1.46.1	T
Health status reporting to SAR.	3.2.1.46.1.1	4.1.46.1.1	T
FIR/ISS health status monitoring.	3.2.1.46.2	4.1.46.2	T
FIR Commanding.	3.2.1.47	4.1.47	NVR
SSC Commanding.	3.2.1.47.1	4.1.47.1	T
Ground Commanding.	3.2.1.47.2	4.1.47.2	T
Commanding through SAR.	3.2.1.47.3	4.1.47.3	T
Manual Inputs	3.2.1.47.4	4.1.47.4	I
Upgrading of FIR maintenance items.	3.2.1.48	4.1.48	A
Use of CIR capabilities.	3.2.1.49	4.1.49	A
Control of FIR.	3.2.1.50a	4.1.50 a.	D
Control of FIR.	3.2.1.50b	4.1.50 b.	D
Physical characteristics	3.2.2	4.2	NVR
FIR dimensional characteristics	3.2.2.1	4.2.1	NVR
FIR launch envelope	3.2.2.1.1	4.2.1.1	A & T
FIR on-orbit envelope	3.2.2.1.2	4.2.1.2	A & T
FIR stowage volume	3.2.2.1.3 a	4.2.1.3 a.	A & T
FIR stowage volume.	3.2.2.1.3 b	4.2.1.3 b.	I
FIR maintenance item stowage	3.2.2.1.4	4.2.1.4	A & T
FIR weight characteristics	3.2.2.2 a.	4.2.2 a.	A & D
FIR weight characteristics	3.2.2.2 b.	4.2.2 b.	A & D
FIR weight characteristics	3.2.2.2 c.	4.2.2 c.	A & D
FIR power.	3.2.2.3a	4.2.3 a.	A
FIR power.	3.2.2.3b	4.2.3 b.	A
FIR environmental control system	3.2.2.3.1	4.2.3.1	A & T

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
power allocation.			
FIR power to PI hardware.	3.2.2.3.2a	4.2.3.2 a.	A
FIR power to PI hardware.	3.2.2.3.2b	4.2.3.2 b.	A
FIR power to PI hardware.	3.2.2.3.2c	4.2.3.2 c.	I, A & T
FIR power to PI hardware.	3.2.2.3.2d	4.2.3.2 d.	I & T
Provide experiment access to cooling media	3.2.2.3.3a	4.2.3.3 a.	A & D
Provide experiment access to cooling media	3.2.2.3.3b	4.2.3.3 b.	D
FIR heat rejection	3.2.2.4	4.2.4	A
PI air cooling .	3.2.2.5	4.2.5	A
Thermal cooling water.	3.2.2.6	4.2.6	A & T
PI water cooling	3.2.2.6.1	4.2.6.1	A
Durability	3.2.2.7 a.	4.2.7 a.	A
Durability	3.2.2.7 b.	4.2.7 b.	A
Transportation and safety requirements	3.2.2.8	4.2.8	NVR
Interfaces	3.2.2.9	4.2.9	I & D
Ground support equipment (GSE) interfaces	3.2.2.9.1 a.	4.2.9.1 a.	I
Ground support equipment (GSE) interfaces	3.2.2.9.1 b.	4.2.9.1 b.	D
Ground support equipment (GSE) interfaces	3.2.2.9.1 c.	4.2.9.1 c.	D
Ground support equipment (GSE) interfaces	3.2.2.9.1 d.	4.2.9.1 d.	T & A
MPLM interfaces	3.2.2.9.2 a.	4.2.9.2 a.	I
MPLM interfaces	3.2.2.9.2 b.	4.2.9.2 b.	A
MPLM interfaces	3.2.2.9.2 c.	4.2.9.2 c.	A
COF interfaces	3.2.2.9.3	4.2.9.3	I
Glove box type access	3.2.2.10 a	4.2.10 a.	A & D
Glove box type access	3.2.2.10 b	4.2.10 b.	A & D
Glove box type access	3.2.2.10 c	4.2.10 c.	A & D
Experiment containment.	3.2.2.11 a	4.2.11 a.	I
Experiment containment.	3.2.2.11 b	4.2.11 b.	I
Reliability	3.2.3	4.3	NVR
Maintainability	3.2.4	4.4	A
FIR maintenance access	3.2.4.1	4.4.1	D
Maintenance item temporary restraint and stowage	3.2.4.2	4.4.2	I
Tool usage for maintenance	3.2.4.3	4.4.3	A
Lockwiring and staking	3.2.4.4	4.4.4	I
Redundant paths	3.2.4.5	4.4.5	A

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
FIR reconfiguration for out-of-tolerance conditions	3.2.4.6	4.4.6	T
Availability	3.2.5	4.5	A
Environmental conditions	3.2.6	4.6	NVR
Shipping and storage environment	3.2.6.1	4.6.1	NVR
Nonoperating atmospheric environment	3.2.6.1.1 a.	4.6.1.1 a.	T
Nonoperating atmospheric environment	3.2.6.1.1 b.	4.6.1.1 b.	A
Nonoperating atmospheric environment	3.2.6.1.1 c.	4.6.1.1 c.	A
MPLM/on-orbit environmental conditions	3.2.6.2	4.6.2	A
On-orbit condensation	3.2.6.3	4.6.3	A
Special environmental conditions	3.2.6.4	4.6.4	NVR
Load requirements	3.2.6.4.1 a.	4.6.4.1 a.	A
Load requirements	3.2.6.4.1 b.	4.6.4.1 b.	A
Load requirements	3.2.6.4.1 c.	4.6.4.1 c.	I
Load requirements	3.2.6.4.1 d.	4.6.4.1 d.	A
Load requirements	3.2.6.4.1 e.	4.6.4.1 e.	A
Load requirements	3.2.6.4.1 f.	4.6.4.1 f.	A
Rack requirements	3.2.6.4.2 a.	4.6.4.2 a.	A
Rack requirements	3.2.6.4.2 b.	4.6.4.2 b.	A
Rack requirements	3.2.6.4.2 c.	4.6.4.2 c.	NVR
Rack requirements	3.2.6.4.2 d.	4.6.4.2 d.	I or A
Rack requirements	3.2.6.4.2 e.	4.6.4.2 e.	A
Rack requirements	3.2.6.4.2 f.	4.6.4.2 f.	A
Rack requirements	3.2.6.4.2 g.	4.6.4.2 g.	A
Rack requirements	3.2.6.4.2 h.	4.6.4.2 h.	I
Rack requirements	3.2.6.4.2 i.	4.6.4.2 i.	I
Rack requirements	3.2.6.4.2 j.	4.6.4.2 j.	A
Rack requirements	3.2.6.4.2 k.	4.6.4.2 k.	A, T
Rack requirements	3.2.6.4.2 l.	4.6.4.2 l.	A or T
Rack requirements	3.2.6.4.2 m.	4.6.4.2 m.	A or T
Rack requirements	3.2.6.4.2 n.	4.6.4.2 n.	A
Electrical requirements	3.2.6.4.3	4.6.4.3	NVR
Steady-state voltage characteristics	3.2.6.4.3.1	4.6.4.3.1	T
Ripple voltage characteristics	3.2.6.4.3.2 a.	4.6.4.3.2 a.	A
Ripple voltage characteristics	3.2.6.4.3.2 b.	4.6.4.3.2 b.	A
Transient voltages	3.2.6.4.3.3	4.6.4.3.3	T or A
Fault clearing and protection	3.2.6.4.3.4	4.6.4.3.4	A
Non-normal voltage range	3.2.6.4.3.5	4.6.4.3.5	A
Power bus isolation	3.2.6.4.3.6 a.	4.6.4.3.6 a.	A
Power bus isolation	3.2.6.4.3.6 b.	4.6.4.3.6 b.	A
Compatibility with soft start/stop	3.2.6.4.3.7	4.6.4.3.7	T

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
remote power controller (RPC)			
Surge current	3.2.6.4.3.8	4.6.4.3.8	T & A
Reverse energy/current	3.2.6.4.3.9	4.6.4.3.9	A
Current protection devices	3.2.6.4.3.10 a.	4.6.4.3.10 a.	T
Current protection devices	3.2.6.4.3.10 b.	4.6.4.3.10 b.	A
Current protection devices	3.2.6.4.3.10 c.	4.6.4.3.10 c.	A
FIR trip ratings	3.2.6.4.3.11	4.6.4.3.11	T & D
Interface B complex load impedances	3.2.6.4.3.12	4.6.4.3.12	T
Large signal stability	3.2.6.4.3.13	4.6.4.3.13	T & A
Maximum ripple voltage emissions	3.2.6.4.3.14	4.6.4.3.14	T & A
Wire derating	3.2.6.4.3.15 a.	4.6.4.3.15 a.	A
Wire derating	3.2.6.4.3.15 b.	4.6.4.3.15 b.	I or A
Exclusive power feeds	3.2.6.4.3.16	4.6.4.3.16	A
Loss of power	3.2.6.4.3.17	4.6.4.3.17	T
Electromagnetic compatibility	3.2.6.4.3.18	4.6.4.3.18	T, A, and/or I
Electrical grounding	3.2.6.4.3.18.1	4.6.4.3.18.1	T & A
Electrical bonding	3.2.6.4.3.18.2	4.6.4.3.18.2	T, A, & I
Cable/wire design and control requirements	3.2.6.4.3.18.3	4.6.4.3.18.3	T, A, or I
Electromagnetic interference	3.2.6.4.3.18.4	4.6.4.3.18.4	T & A
Electrostatic discharge	3.2.6.4.3.18.5	4.6.4.3.18.5	T or A & I
Alternating current (ac) magnetic fields	3.2.6.4.3.18.6	4.6.4.3.18.6	T
Direct current (dc) magnetic fields	3.2.6.4.3.18.7	4.6.4.3.18.7	T or A
Corona	3.2.6.4.3.18.8	4.6.4.3.18.8	A or T
Lightning	3.2.6.4.3.18.9	4.6.4.3.18.9	A
EMI susceptibility for safety-critical circuits	3.2.6.4.3.18.10	4.6.4.3.18.10	T & A
Transportability	3.2.7	4.7	A
FIR launch and return	3.2.7.1	4.7.1	A
Design and construction	3.3	4.8	NVR
Materials, processes, and parts	3.3.1	4.8.1	NVR
FIR specific material requirements	3.3.1.1	4.8.1.1	NVR
Materials – general	3.3.1.1.1	4.8.1.1.1	I
Fluids	3.3.1.1.2 a.	4.8.1.1.2 a.	T
Fluids	3.3.1.1.2 b.	4.8.1.1.2 b.	T
Fluids	3.3.1.1.2 c.	4.8.1.1.2 c.	I or A
Connectors	3.3.1.1.3	4.8.1.1.3	I
External cleanliness	3.3.1.1.4 a.	4.8.1.1.4 a.	I
External cleanliness	3.3.1.1.4 b.	4.8.1.1.4 b.	I
Toxic products and formulations	3.3.1.2	4.8.1.2	I
Volatile organic compounds	3.3.1.3	4.8.1.3	I
Hazardous materials	3.3.1.4	4.8.1.4	I

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
Protective coatings	3.3.1.5	4.8.1.5	I
Electromagnetic radiation	3.3.2	4.8.2	NVR
Ionizing radiation	3.3.2.1	4.8.2.1	NA
Nonionizing radiation	3.3.2.2	4.8.2.2	NA
Operating environment	3.3.2.3	4.8.2.3	NA
Generated environment	3.3.2.4	4.8.2.4	NA
Nameplates and product marking	3.3.3	4.8.3	NVR
Nameplates	3.3.3.1	4.8.3.1	NVR
FIR identification and marking	3.3.3.2	4.8.3.2	I
FIR component identification and marking	3.3.3.2.1 a. – d.	4.8.3.2.1 a-d	I
FIR lighting design	3.3.3.2.2 a.	4.8.3.2.2 a.	T or I
FIR lighting design	3.3.3.2.2 b.	4.8.3.2.2 b.	T
FIR lighting design	3.3.3.2.2 c.	4.8.3.2.2 c.	A or T
FIR lighting design	3.3.3.2.2 d.	4.8.3.2.2 d.	I
FIR lighting design	3.3.3.2.2 e.	4.8.3.2.2 e.	I
FIR lighting design	3.3.3.2.2 f.	4.8.3.2.2 f.	I
Touch temperature warning labels	3.3.3.2.3	4.8.3.2.3	A & I
Connector coding and labeling	3.3.3.2.4 a.	4.8.3.2.4 a.	I
Connector coding and labeling	3.3.3.2.4 b.	4.8.3.2.4 b.	I
Connector coding and labeling	3.3.3.2.4 c.	4.8.3.2.4 c.	I
Portable fire extinguisher (PFE) and fire detection indicator labeling	3.3.3.3 a.	4.8.3.3 a.	I
Portable fire extinguisher (PFE) and fire detection indicator labeling	3.3.3.3 b.	4.8.3.3 b.	I
Electrostatic discharge sensitive parts labeling	3.3.3.4	4.8.3.4	I
Workmanship	3.3.4	4.8.4	I
Interchangeability	3.3.5	4.8.5	I
Safety	3.3.6	4.8.6	A, I, & T
Fire prevention	3.3.6.1	4.8.6.1	A & I
Smoke detector	3.3.6.1.1 a.	4.8.6.1.1 a.	I
Smoke detector	3.3.6.1.1 b.	4.8.6.1.1 b.	I & D
Maintenance switch, smoke detector, smoke indicator, and FIR fan interfaces	3.3.6.1.1.1	4.8.6.1.1.1	I & T
Smoke indicator analog interface characteristics	3.3.6.1.1.2	4.8.6.1.1.2	I
Discrete command built-in-test interface characteristics	3.3.6.1.1.3	4.8.6.1.1.3	I
Smoke detector electrical interfaces	3.3.6.1.1.4	4.8.6.1.1.4	I & T
Fan ventilation status electrical interfaces	3.3.6.1.1.5	4.8.6.1.1.5	I

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Rack maintenance switch (rack power switch)/fire detection support interface connector	3.3.6.1.1.6	4.8.6.1.1.6	I
Rack maintenance switch (rack power switch)/fire detection support interface connector	3.3.6.1.1.6 a.	4.8.6.1.1.6 a.	NVR
Rack maintenance switch (rack power switch)/fire detection support interface connector	3.3.6.1.1.6 b.	4.8.6.1.1.6 b.	I
Rack maintenance switch (rack power switch)/fire detection support interface connector	3.3.6.1.1.6 c.	4.8.6.1.1.6 c.	I
Fire detection indicator	3.3.6.1.2 a.	4.8.6.1.2 a.	T & I
Fire detection indicator	3.3.6.1.2 b.	4.8.6.1.2 b.	I
Forced air circulation indication	3.3.6.1.3	4.8.6.1.3	T
Fire parameter monitoring in the FIR	3.3.6.1.4 a.	4.8.6.1.4 a.	T
Fire parameter monitoring in the FIR	3.3.6.1.4 b.	4.8.6.1.4 b.	T
Fire suppression access port accessibility	3.3.6.1.5 a.	4.8.6.1.5 a.	I & A
Fire suppression access port accessibility	3.3.6.1.5 b.	4.8.6.1.5 b.	D
Fire suppressant distribution	3.3.6.1.6	4.8.6.1.6	A or T
FIR front surface temperature	3.3.6.2	4.8.6.2	A or T
Electrical hazards	3.3.6.3 a.	4.8.6.3 a.	NVR
Electrical hazards	3.3.6.3 b.	4.8.6.3 b.	A and/or T
Electrical hazards	3.3.6.3 c.	4.8.6.3 c.	A and/or T
Electrical hazards	3.3.6.3 d.	4.8.6.3 d.	A and/or T
Connector mating	3.3.6.4	4.8.6.4	A, I, & D
Mating/demating of powered connectors	3.3.6.5	4.8.6.5	A
Safety-critical circuit redundancy	3.3.6.6	4.8.6.6	A
Rack maintenance switch (rack power switch)	3.3.6.7	4.8.6.7	I & D
Power switches/controls	3.3.6.8 a.	4.8.6.8 a.	A
Power switches/controls	3.3.6.8 b.	4.8.6.8 b.	A
Power switches/controls	3.3.6.8 c.	4.8.6.8 c.	A
Ground fault circuit interrupters (GFCI)/portable equipment dc sourcing voltage	3.3.6.9 a.	4.8.6.9 a.	A
Ground fault circuit interrupters (GFCI)/portable equipment dc sourcing voltage	3.3.6.9 b.	4.8.6.9 b.	T
Ground fault circuit interrupters	3.3.6.9 c.	4.8.6.9 c.	T or A

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(GFCI)/portable equipment dc sourcing voltage			
Ground fault circuit interrupters (GFCI)/portable equipment dc sourcing voltage	3.3.6.9 d.	4.8.6.9 d.	A & T
Ground fault circuit interrupters (GFCI)/portable equipment dc sourcing voltage	3.3.6.9 e.	4.8.6.9 e.	T or A
Ground fault circuit interrupters (GFCI)/portable equipment dc sourcing voltage	3.3.6.9 f.	4.8.6.9 f.	T
Ground fault circuit interrupters (GFCI)/portable equipment dc sourcing voltage	3.3.6.9 g.	4.8.6.9 g.	A & D
Portable equipment/power cords	3.3.6.10 a.	4.8.6.10 a.	A
Portable equipment/power cords	3.3.6.10 b.	4.8.6.10 b.	A
Overload protection	3.3.6.11	4.8.6.11	NVR
Device accessibility	3.3.6.11.1	4.8.6.11.1	I
Extractor-type fuse holder	3.3.6.11.2	4.8.6.11.2	D
Overload protection location	3.3.6.11.3	4.8.6.11.3	I
Overload protection identification	3.3.6.11.4	4.8.6.11.4	I
Automatic restart protection	3.3.6.11.5	4.8.6.11.5	D
Sharp edges and corners protection	3.3.6.12	4.8.6.12	I
Holes	3.3.6.13	4.8.6.13	A & I
Latches	3.3.6.14	4.8.6.14	I
Screw and bolts	3.3.6.15	4.8.6.15	A & I
Securing pins	3.3.6.16	4.8.6.16	A
Levers, cranks, hooks, and controls	3.3.6.17	4.8.6.17	A & I
Burrs	3.3.6.18	4.8.6.18	I
Locking wires	3.3.6.19 a.	4.8.6.19 a.	A
Locking wires	3.3.6.19 b.	4.8.6.19 b.	I
Audio devices (displays)	3.3.6.20 a.	4.8.6.20 a.	A
Audio devices (displays)	3.3.6.20 b.	4.8.6.20 b.	D
Audio devices (displays)	3.3.6.20 c.	4.8.6.20 c.	A & D
Egress	3.3.6.21	4.8.6.21	A
Failure tolerance	3.3.6.22	4.8.6.22	A
Failure propagation	3.3.6.23 a.	4.8.6.23 a.	A
Failure propagation	3.3.6.23 b.	4.8.6.23 b.	A
Incorrect equipment installation	3.3.6.24	4.8.6.24	A
Chemical releases	3.3.6.25	4.8.6.25	A
Single event effect (SEE) ionizing radiation	3.3.6.26	4.8.6.26	A

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Potential hazardous conditions.	3.3.6.27 a	4.8.6.27 a	I & D
Potential hazardous conditions.	3.3.6.27 b	4.8.6.27 b	I & D
Withstand external environment.	3.3.6.28	4.8.6.28	I & D
Human performance/human engineering	3.3.7	4.8.7	NVR
Strength requirements	3.3.7.1 a. (1)	4.8.7.1 a. (1)	A or D
Strength requirements	3.3.7.1 a. (2)	4.8.7.1 a. (2)	A or D
Strength requirements	3.3.7.1 a. (3)	4.8.7.1 a. (3)	A or D
Strength requirements	3.3.7.1 b.	4.8.7.1 b.	A or D
Adequate crew clearance	3.3.7.2	4.8.7.2	A or D
Accessibility	3.3.7.3 a.	4.8.7.3 a.	A or D
Accessibility	3.3.7.3 b.	4.8.7.3 b.	A or D
Full size range accommodation	3.3.7.4	4.8.7.4	A
Housekeeping closures and covers	3.3.7.5	4.8.7.5	I
Built-in housekeeping control	3.3.7.6 a.	4.8.7.6 a.	I
Built-in housekeeping control	3.3.7.6 b.	4.8.7.6 b.	A or D
One-handed operation	3.3.7.7	4.8.7.7	D
Acoustic requirements	3.3.7.8	4.8.7.8	NVR
Continuous noise limits	3.3.7.8.1	4.8.7.8.1	A & T
Intermittent noise limits	3.3.7.8.2	4.8.7.8.2	A & T
FIR hardware mounting	3.3.7.9	4.8.7.9	NVR
Equipment mounting	3.3.7.9.1	4.8.7.9.1	A or D
Drawers and hinged panel	3.3.7.9.2	4.8.7.9.2	A
Alignment	3.3.7.9.3	4.8.7.9.3	A
Slide-out stops	3.3.7.9.4	4.8.7.9.4	I, A, or D
Push-pull force	3.3.7.9.5	4.8.7.9.5	A
Access	3.3.7.9.6	4.8.7.9.6	A or D
Covers	3.3.7.9.7	4.8.7.9.7	A
Self-supporting covers	3.3.7.9.8	4.8.7.9.8	A
Unique tools	3.3.7.9.9	4.8.7.9.9	A
Connectors	3.3.7.10	4.8.7.10	NVR
One-handed operation	3.3.7.10.1	4.8.7.10.1	A or D
Accessibility	3.3.7.10.2 a. (1)	4.8.7.10.2 a. (1)	A or D
Accessibility	3.3.7.10.2 a. (2)	4.8.7.10.2 a. (2)	A or D
Accessibility	3.3.7.10.2 b.	4.8.7.10.2 b.	A
Ease of disconnect	3.3.7.10.3 a.	4.8.7.10.3 a.	A
Ease of disconnect	3.3.7.10.3 b.	4.8.7.10.3 b.	A
Indication of pressure/flow	3.3.7.10.4	4.8.7.10.4	A
Self locking	3.3.7.10.5	4.8.7.10.5	A
Connector arrangement	3.3.7.10.6 a.	4.8.7.10.6 a.	I

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
Connector arrangement	3.3.7.10.6 b.	4.8.7.10.6 b.	I
Arc containment	3.3.7.10.7	4.8.7.10.7	A
Connector protection	3.3.7.10.8	4.8.7.10.8	A
Connector shape	3.3.7.10.9	4.8.7.10.9	A
Fluid and gas line connectors	3.3.7.10.10	4.8.7.10.10	A
Alignment marks or pin guides	3.3.7.10.11	4.8.7.10.11	I
Orientation	3.3.7.10.12	4.8.7.10.12	A
Hose/cable restraints	3.3.7.10.13 a.	4.8.7.10.13 a.	I
Hose/cable restraints	3.3.7.10.13 b.	4.8.7.10.13 b.	I
Hose/cable restraints	3.3.7.10.13 c.	4.8.7.10.13 c.	NVR
Hose/cable restraints	3.3.7.10.13 d.	4.8.7.10.13 d.	I
Fasteners	3.3.7.11	4.8.7.11	NVR
Non-threaded fasteners status indication	3.3.7.11.1	4.8.7.11.1	D or I
Mounting bolt/fastener spacing	3.3.7.11.2	4.8.7.11.2	I
Multiple fasteners	3.3.7.11.3	4.8.7.11.3	I
Captive fasteners	3.3.7.11.4	4.8.7.11.4	A
Quick release fasteners	3.3.7.11.5 a.	4.8.7.11.5 a.	I
Quick release fasteners	3.3.7.11.5 b.	4.8.7.11.5 b.	I
Threaded fasteners	3.3.7.11.6	4.8.7.11.6	I
Over center latches	3.3.7.11.7 a.	4.8.7.11.7 a.	I
Over center latches	3.3.7.11.7 b.	4.8.7.11.7 b.	I
Over center latches	3.3.7.11.7 c.	4.8.7.11.7 c.	I
Winghead fasteners	3.3.7.11.8	4.8.7.11.8	I
Fasteners head type	3.3.7.11.9 a.	4.8.7.11.9 a.	I
Fasteners head type	3.3.7.11.9 b.	4.8.7.11.9 b.	I
Fasteners head type	3.3.7.11.9 c.	4.8.7.11.9 c.	I
One-handed operation	3.3.7.11.10	4.8.7.11.10	A or D
Access holes	3.3.7.11.11	4.8.7.11.11	I
Controls and displays	3.3.7.12	4.8.7.12	NVR
Controls spacing design requirements	3.3.7.12.1	4.8.7.12.1	I
Accidental actuation	3.3.7.12.2	4.8.7.12.2	NVR
Protective methods	3.3.7.12.2.1	4.8.7.12.2.1	I
Noninterference	3.3.7.12.2.2	4.8.7.12.2.2	I
Dead-man controls	3.3.7.12.2.3	4.8.7.12.2.3	NVR
Barrier guards	3.3.7.12.2.4	4.8.7.12.2.4	I
Recessed switch protection	3.3.7.12.2.5	4.8.7.12.2.5	I
Position indication	3.3.7.12.2.6	4.8.7.12.2.6	I
Hidden controls	3.3.7.12.2.7	4.8.7.12.2.7	I
Hand controllers	3.3.7.12.2.8	4.8.7.12.2.8	I
Valve controls	3.3.7.13 a.	4.8.7.13 a.	I
Valve controls	3.3.7.13 b.	4.8.7.13 b.	I

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Valve controls	3.3.7.13 c.	4.8.7.13 c.	I
Valve controls	3.3.7.13 d.	4.8.7.13 d.	I
Valve controls	3.3.7.13 e.	4.8.7.13 e.	I
Toggle switches	3.3.7.14	4.8.7.14	I
Restraints and mobility aids	3.3.7.15	4.8.7.15	D or A
Captive parts	3.3.7.16	4.8.7.16	I
Handle and grasp area design requirements	3.3.7.17	4.8.7.17	NVR
Handles and restraints	3.3.7.17.1	4.8.7.17.1	D or I
Handle location/front access	3.3.7.17.2	4.8.7.17.2	I
Handle dimensions	3.3.7.17.3	4.8.7.17.3	A or D
Non-fixed handles design requirements	3.3.7.17.4 a.	4.8.7.17.4 a.	A & D
Non-fixed handles design requirements	3.3.7.17.4 b.	4.8.7.17.4 b.	D
Non-fixed handles design requirements	3.3.7.17.4 c.	4.8.7.17.4 c.	I & D
Design requirements	3.3.8	4.8.8	NVR
Units of measure	3.3.8.1	4.8.8.1	I
Margins of safety/factors of safety	3.3.8.2	4.8.8.2	I
Allowable mechanical properties	3.3.8.3	4.8.8.3	I
Fracture control	3.3.8.4	4.8.8.4	I
FIR computer resource requirements	3.4	4.9	NVR
FIR computer hardware design considerations	3.4.1 a.	4.9.1 a.	T
FIR computer hardware design considerations	3.4.1 b.	4.9.1 b.	T
FIR computer hardware design considerations	3.4.1 c	4.9.1 c.	T
Command and data requirements	3.4.1.1	4.9.1.1	NVR
Word/byte notations	3.4.1.1.1	4.9.1.1.1	I
Data types	3.4.1.1.2	4.9.1.1.2	I
Data transmissions	3.4.1.1.3 a.	4.9.1.1.3 a.	I
Data transmissions	3.4.1.1.3 b.	4.9.1.1.3 b.	I
Data transmissions	3.4.1.1.3 c.	4.9.1.1.3 c.	I
Consultative committee for space data systems	3.4.1.1.4 a.-c.	4.9.1.1.4	A or T
CCSDS data packets	3.4.1.1.4.1	4.9.1.1.4.1	T
CCSDS primary header	3.4.1.1.4.1.1	4.9.1.1.4.1.1	T
CCSDS secondary header	3.4.1.1.4.1.2	4.9.1.1.4.1.2	T
CCSDS data field	3.4.1.1.4.1.3	4.9.1.1.4.1.3	T
CCSDS application process identification field	3.4.1.1.4.1.4	4.9.1.1.4.1.4	T
CCSDS time codes	3.4.1.1.4.2	4.9.1.1.4.2	NVR
CCSDS unsegmented time	3.4.1.1.4.2.1	4.9.1.1.4.2.1	T

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CCSDS segmented time	3.4.1.1.4.2.2	4.9.1.1.4.2.2	T
MIL-STD-1553B low rate data link (LRDL)	3.4.1.1.5	4.9.1.1.5	T
Standard messages	3.4.1.1.5.1	4.9.1.1.5.1	I & T
Commanding	3.4.1.1.5.2	4.9.1.1.5.2	T
Health and status data	3.4.1.1.5.3	4.9.1.1.5.3	T & I
Safety data	3.4.1.1.5.4	4.9.1.1.5.4	T
Caution and warning	3.4.1.1.5.5	4.9.1.1.5.5	NVR
Class 2 – warning	3.4.1.1.5.5.1	4.9.1.1.5.5.1	A & T
Class 3 – caution	3.4.1.1.5.5.2	4.9.1.1.5.5.2	A & T
Class 4 – advisory	3.4.1.1.5.5.3	4.9.1.1.5.5.3	A & T
Service requests	3.4.1.1.5.6	4.9.1.1.5.6	T
File transfer	3.4.1.1.5.7	4.9.1.1.5.7	T
Low rate telemetry	3.4.1.1.5.8	4.9.1.1.5.8	T
Defined mode codes	3.4.1.1.5.9	4.9.1.1.5.9	T
Implemented mode codes	3.4.1.1.5.10	4.9.1.1.5.10	T
Illegal commands	3.4.1.1.5.11	4.9.1.1.5.11	T
LRDL interface characteristics	3.4.1.1.5.12 a.	4.9.1.1.5.12 a.	I
LRDL interface characteristics	3.4.1.1.5.12 b.	4.9.1.1.5.12 b.	I
Remote terminal hardwired address coding	3.4.1.1.5.12.1	4.9.1.1.5.12.1	T
LRDL signal characteristics	3.4.1.1.5.12.2	4.9.1.1.5.12.2	T
LRDL cabling	3.4.1.1.5.12.3	4.9.1.1.5.12.3	I
Multi-bus isolation	3.4.1.1.5.12.4	4.9.1.1.5.12.4	T
Medium rate data link (MRDL)	3.4.1.1.6	4.9.1.1.6	NVR
MRDL protocol	3.4.1.1.6.1	4.9.1.1.6.1	I & T
FIR protocols on the MRDL	3.4.1.1.6.2	4.9.1.1.6.2	I & T
MRDL address	3.4.1.1.6.3	4.9.1.1.6.3	I & T
FIR MRDL connectivity	3.4.1.1.6.4 a.	4.9.1.1.6.4 a.	I
FIR MRDL connectivity	3.4.1.1.6.4 b.	4.9.1.1.6.4 b.	T
FIR MRDL connectivity	3.4.1.1.6.4 c.	4.9.1.1.6.4 c.	T
FIR MRDL connectivity	3.4.1.1.6.4 d.	4.9.1.1.6.4 d.	A
MRDL connector/pin assignments and wire requirements	3.4.1.1.6.5 a.	4.9.1.1.6.5 a.	I
MRDL connector/pin assignments and wire requirements	3.4.1.1.6.5 b.	4.9.1.1.6.5 b.	I
MRDL connector/pin assignments and wire requirements	3.4.1.1.6.5 c.	4.9.1.1.6.5 c.	I
MRDL signal characteristics	3.4.1.1.6.6	4.9.1.1.6.6	I & T
MRDL cable characteristics	3.4.1.1.6.7	4.9.1.1.6.7	I
Differential characteristic impedance	3.4.1.1.6.7.1	4.9.1.1.6.7.1	T
FIR to high-rate frame multiplexer	3.4.1.1.7	4.9.1.1.7	T

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(HRFM) protocols			
High rate data link (HRDL) physical signaling data rates	3.4.1.1.7.1	4.9.1.1.7.1	T & A
High rate data link (HRDL) physical signaling data rates	3.4.1.1.7.1 a.	4.9.1.1.7.1 a.	T
High rate data link (HRDL) physical signaling data rates	3.4.1.1.7.1 b.	4.9.1.1.7.1 b.	T
Encoding	3.4.1.1.7.2	4.9.1.1.7.2	I & T
Symbols used in testing	3.4.1.1.7.3	4.9.1.1.7.3	T
FIR HRDL transmitted optical power	3.4.1.1.7.4	4.9.1.1.7.4	T
HRDL fiber optic cable	3.4.1.1.7.5	4.9.1.1.7.5	I
HRDL fiber optic bend radius	3.4.1.1.7.6	4.9.1.1.7.6	I
HRDL connectors and fiber	3.4.1.1.7.7 a.	4.9.1.1.7.7 a.	I
HRDL connectors and fiber	3.4.1.1.7.7 b.	4.9.1.1.7.7 b.	I
HRDL connectors and fiber	3.4.1.1.7.7 c.	4.9.1.1.7.7 c.	I
Station support computer (SSC)	3.4.1.1.8 a.	4.9.1.1.8 a.	I
Station support computer (SSC)	3.4.1.1.8 b.	4.9.1.1.8 b.	D
FIR national television systems committee (NTSC) video and audio interface requirements	3.4.1.1.9	4.9.1.1.9	NVR
FIR NTSC video characteristics	3.4.1.1.9.1	4.9.1.1.9.1	T
Pulse frequency modulation NTSC fiber optic video characteristics	3.4.1.1.9.2	4.9.1.1.9.2	T
FIR NTSC PFM video transmitted optical power	3.4.1.1.9.3	4.9.1.1.9.3	T
Fiber optic cable characteristics	3.4.1.1.9.4	4.9.1.1.9.4	I
PFM NSTC video fiber optic cable bend radius	3.4.1.1.9.5	4.9.1.1.9.5	I
Flexibility and expansion	3.4.2 a.	4.9.2 a.	T
Flexibility and expansion	3.4.2 b.	4.9.2 b.	A & T
Flexibility and expansion	3.4.2 c.	4.9.2 c.	I
Flexibility and expansion	3.4.2 d.	4.9.2 d.	D
Flexibility and expansion	3.4.2 e.	4.9.2 e.	T
Flexibility and expansion	3.4.2 f.	4.9.2 f.	T
Flexibility and expansion	3.4.2 g.	4.9.2 g.	A
Flexibility and expansion	3.4.2 h.	4.9.2 h.	A
Flexibility and expansion	3.4.2 i.	4.9.2 i.	A
Flexibility and expansion	3.4.2 j.	4.9.2 j.	A
Flexibility and expansion	3.4.2 k.	4.9.2 k.	A
Flexibility and expansion	3.4.2 l.	4.9.2 l.	A
Software portability	3.4.3 a.	4.9.3 a.	T
Software portability	3.4.3 b.	4.9.3 b.	T

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
Data date/time stamps	3.4.4a	4.9.4 a.	I & T
Data date/time stamps	3.4.4b	4.9.4 b.	I & T
Logistics	3.5	4.10	NVR
Maintenance	3.5.1	4.10.1	D
Supply	3.5.2	4.10.2	A
Facilities and facility equipment	3.5.3	4.10.3	NA
Personnel and training	3.6	4.11	NVR
Personnel	3.6.1 a.	4.11.1 a.	D
Personnel	3.6.1 b.	4.11.1 b.	T
Personnel	3.6.1 c.	4.11.1 c.	D
Training	3.6.2	4.11.2	D
Major component characteristics	3.7	4.12	I
Water Thermal Control System (WTCS)	3.7.1 a. (1)	4.12.1 a. (1)	T
Water Thermal Control System (WTCS)	3.7.1 a. (2)	4.12.1 a. (2)	A
Water Thermal Control System (WTCS)	3.7.1 b.	4.12.1 b.	T
Water Thermal Control System (WTCS)	3.7.1 c.	4.12.1 c.	A or T
Water Thermal Control System (WTCS)	3.7.1 d.	4.12.1 d.	T & A
Water Thermal Control System (WTCS)	3.7.1 e.	4.12.1 e.	NVR
Water Thermal Control System (WTCS)	3.7.1 f. (1)	4.12.1 f. (1)	T & A
Water Thermal Control System (WTCS)	3.7.1 f. (2)	4.12.1 f. (2)	A
Water Thermal Control System (WTCS)	3.7.1 f. (3)	4.12.1 f. (3)	T & A
Water Thermal Control System (WTCS)	3.7.1 g.	4.12.1 g.	T
Water Thermal Control System (WTCS)	3.7.1 h.	4.12.1 k.	A &/or T
Water Thermal Control System (WTCS)	3.7.1 i.	4.12.1 i.	T
Water Thermal Control System (WTCS)	3.7.1 j.	4.12.1 j.	T or A
Water Thermal Control System (WTCS)	3.7.1 k.	4.12.1 k.	T
Water Thermal Control System (WTCS)	3.7.1 l.	4.12.1 l.	T or A
Water Thermal Control System	3.7.1 m.	4.12.1 m.	A

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
(WTCS)			
Water Thermal Control System (WTCS)	3.7.1 n.	4.12.1 n.	I or D
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 a.	4.12.2 a.	T & A
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 b.	4.12.2 b.	T & A
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 c.	4.12.2 c.	A
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 d.	4.12.2 d.	T
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 e.	4.12.2 e.	T
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 f.	4.12.2 f.	A or T
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 g.	4.12.2 g.	A
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 h.	4.12.2 h.	A
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 i.	4.12.2 i.	A
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 j.	4.12.2 j.	NVR
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 k.	4.12.2 k.	A
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 l.	4.12.2 l.	NVR
Vacuum exhaust system/waste gas system (VES/WGS) requirements	3.7.2 m.	4.12.2 m.	I & A
ISS nitrogen usage requirements	3.7.3 a.	4.12.3 a.	T
ISS nitrogen usage requirements	3.7.3 b.	4.12.3 b.	T & A
ISS nitrogen usage requirements	3.7.3 c.	4.12.3 c.	T and/or A
ISS nitrogen usage requirements	3.7.3 d.	4.12.3 d.	T
Vacuum resource system/vacuum vent system((VRS/VVS) requirements.	3.7.4 a	4.12.4 a.	T
Vacuum resource system/vacuum vent system((VRS/VVS) requirements.	3.7.4 b	4.12.4 b.	T & A
Vacuum resource system/vacuum vent system((VRS/VVS) requirements.	3.7.4 c	4.12.4 c.	A
Vacuum resource system/vacuum vent system((VRS/VVS) requirements.	3.7.4 d	4.12.4 d.	T
Vacuum resource system/vacuum vent system((VRS/VVS) requirements.	3.7.4 e	4.12.4 e.	NVR

Paragraph Name	Section 3 Requirement Number	FIR-PLN-0147 Requirement Number	Verification Method
Preparation for delivery	5.0	4.13	NVR
Preservation	5.1	4.13.1	NVR
Packing	5.2	4.13.2	I
Launch configured FIR	5.2.1	4.13.2.1	I
Cleanliness	5.2.1.1	4.13.2.1.1	I
Procedures	5.2.1.2	4.13.2.1.2	I
Flight spares and other equipment	5.2.2	4.13.2.2	I
Marking and labeling	5.3	4.13.3	NA
Marking for shipment	5.4	4.13.4	I

APPENDIX G EXCEPTIONS

G.1 Scope.

This appendix documents the approved exceptions to this document.

G.2 3.2.4.1 FIR maintenance access.

The FIR shall be designed to allow for the replacement of assemblies and components and the performance of other maintenance activities without rotating the FIR from its installed position within the US Lab.

G.2.1 Exceptions to FIR maintenance access.

a. The FIR design requires rack rotation for ARIS maintenance activities.
b. The FIR design requires rack rotation for EPCU maintenance activities.

G.2.2 Rationales for exceptions to FIR maintenance access.

a. In order to minimize the impact to useable volume within the FIR, ARIS components are located in places not easily accessible when the FIR is in its on-orbit configuration to meet its design requirements. A severe cost and science impact would be incurred to redesign the FIR to meet this requirement for ARIS.
b. The EPCU design would require modifications to its mounting equipment and umbilical design to meet the FIR maintenance requirement. The FIR would only need to be rotated from its installed position in the event of an off-nominal maintenance activity or replacement of the EPCU.

G.3 3.2.2.1.2 FIR on-orbit envelope.

The FIR, with applicable PI hardware, shall have an on-orbit envelope as specified in SSP 41017 Part1, paragraph 3.2.1.1.2 and shall follow the on-orbit payload protrusion requirements as specified in SSP 57000, paragraph 3.1.1.7.

G.3.1 Exceptions to FIR on-orbit envelope.

a. Exception to the on-orbit temporary protrusions as specified in SSP 57000 to allow the FIR Optic Bench to protrude into the aisle for maintenance activities.
b. Exception to the on-orbit temporary protrusions as specified in SSP 57000 to allow the FIR doors to protrude beyond the specified envelope for maintenance activities.

G.3.2 Rationales for exceptions to FIR on-orbit envelope.

a. The FIR Optic Bench design minimizes crew resources and saves space by providing an alternative to rotating the rack for reconfiguration. The Optic Bench provides structural support, electrical connections, and mounting connections for all science support hardware. The Optic Bench will only be deployed while crew attended, meets human interface requirements for interfaces and operation as specified in SSP 57000, and allows for rapid reconfiguration of hardware for increased science throughput. The design allows the Optic Bench to be quickly restowed and does not interfere with egress requirements. This exception has been approved by the ISS Payload Office under PIRN No. SSP 57218-NA-0001.

b. The FIR door design does not interfere with the volumes for access and egress. The door sweep does not extend beyond the protrusion violation in the Optic Bench. The doors will only be open to perform maintenance and science activities on the FIR. The exception has been approved by the ISS payload Office under PIRN No. SSP 57218-NA-001.

G.4 3.2.2.11 Sealed container for fluids experiment.

a. The FIR shall not preclude the mounting of a sealed container, up to the size of a double middeck locker, to the front of the optics bench.

G.4.1 Exception to sealed container for fluids experiment.

The FIR System design does not provide a sealed container for the fluids experiment.

G.4.2 Rationale for exception to sealed container for fluids experiment.

The Light Microscopy Module (LMM) does provide this type of capability. PI experiment payloads that will not operate within LMM will be required to provide their own sealed container.

G.5 3.2.1.6 Maintain test cell temperature.

The facility shall support the ability of PI experiment payload to maintain required test cell (and other) temperatures inside the PI hardware over a minimum range of –20 to 100 °C.

G.5.1 Exception to maintain test cell temperature.

The FIR System design does not provide sufficient high and low temperature heat sinks to achieve this temperature range. It is assumed that the PI experiment payload will provide its own mechanism for maintaining test cell temperatures in this range.

G.5.2 Rationale for exception to maintain test cell temperature.

This requirement traces to SRED F4.2. The ISS moderate temperature loop water inlet temperature to the FIR system is in the range of 16-18 °C. In addition, the FCF design does not provide any mechanism of heating test cells.

G.6 3.2.1.13 Accommodate test point durations.

FIR shall accommodate the range of quantity of test points and test point durations of the fluid physics basis experiments per the estimates in Figure 7. Figure 7 is a graphical statement of the requirements.

G.6.1 Exception to accommodate test point durations.

The FIR System cannot guarantee that the microgravity levels will be maintained for the duration of the basis experiments.

G.6.2 Rationale for exception to accommodate test point durations.

This requirement traces to the SRED requirement F12. The FCF System is dependent on the microgravity environment provided by the ISS. The microgravity duration is based on the ISS timeline, presented in paragraph 4.2.1 of SSP 57020, that defines 90 day cycles for rendezvous, resupply and coast (including maintenance) periods. This paragraph required that 180 days per year of microgravity be provided and that at least two 30 day periods of microgravity be provided per year.

G.7 3.2.1.21 Particle speed vs. field of views.

FIR shall accommodate the range of fields of view (FOV) and expected particle velocities required by the basis experiments per the estimates in Figure 9. Figure 9 is a graphical statement of the requirements to be enveloped.

G.7.1 Exception to particle speed vs. field of views.

Based on bread board test results, and even with the anticipated engineering unit, it is not expected that FIR will meet all the requirements here. Most of the points in Figure 9 can be met with the hi-resolution camera shutter speed, and many more can be met with the High Frame Rate Camera which will eventually be part of the suite of diagnostics provided by FIR. Exposures shorter than 77 µs may be questionable. This only affects experiment f13.

G.7.2 Rationale for exception to particle speed vs. field of views.

The camera will be tested in conjunction with the light source to ensure that camera and source combination provides adequate illumination for the shutter speed to be increased and provide useful scientific data.

G.8 3.2.1.9 Background lighting.

FIR shall provide uniform, broad band lighting (nominally white light) at the payload equipment test cell. Intensity and uniformity shall be consistent with image resolution requirements. The absolute mean intensity shall be variable over a wide range. The mean intensity shall be determinable with an accuracy of approximately 1 percent before, during, and after an experiment test point run. The mean intensity shall be stable within approximately 1 percent during a test point run.

The dimensions of the illuminated area shall be capable of adjustment over a range of sizes as required by the basis experiments; however, the nominal size shall be an approximately 10 cm x 10 cm illuminated field of view.

G.8.1 Exception to background lighting.

a. The SRED Compliance Verification Method for measuring light uniformity outlined in Appendix D may be unrealistic
b. The SRED requirement that the illuminated area shall be capable of adjustment over a range of sizes will not be met.

G.8.2 Rationale for exception to background lighting.

a. The FIR will provide one background lighting package with two bulbs. Two fiber bundles can be quickly attached, one to each bulb. One fiber bundle will be terminated with a fiber weave panel, the second fiber bundle will be terminated with an end that will be capable of connecting to a PI provided lens. The PI provided lens can be configured to produce illumination at the test cell which has been optimized for the desired configuration. Uniformity of the background lighting packages will be tested via image analysis of test images. The uniformity of the backlight will be compared to that of a 20-inch uniform source integrating sphere with an 8 inch exit port. This type of large integrating sphere is generally accepted as the best possible method for providing uniform illumination. Because of its large size, this instrument is not feasible for flight, but it will be used to compare the performance of the FIR light packages to the best uniform illuminator available on the ground. The SRED Compliance Verification Method for light uniformity outlined in Appendix D of the SRED will be performed for both the "lab standard" as well as the FIR light packages. It has been demonstrated that not even the uniform source integrating sphere can meet the requirement that the standard deviation of the intensity across the illuminated area should not exceed 1 percent. Therefore, if the test method outlined in the SRED Appendix D proves to be unrealistic, changes to test procedures will be made and documented. Even for a perfectly uniform light source, uniformity of the irradiance across a plane object will depend on the object's distance from the source as well as the size of the illuminated area. Uniformity testing for the fiber bundle with an attached lens can only be done for an in-house lenses but all PI provided lenses can be characterized prior to use and then baselined for on orbit use.
b. Uniformity tests will be performed for fields of view ranging from 300 microns x 300 microns to 100 mm x 100 mm, and at source to object distances ranging from zero to 500 mm. The tests will be conducted at maximum light output, as well as one or two lower levels. Intensity levels will be measured at a range of distances from the sources and tabulated. Measurements will be performed with calibrated power meters with an accuracy of +/- 5%. Intensity stability will be established by measuring intensities at discrete intervals over a 6 hour period. Light availability from the

backlight packages will be compared to light requirements of the camera and lens systems at various shutter speeds and apertures. The white fiber weave panel was chosen to provide the necessary illumination for a 10 cm x 10 cm field of view. Adjustment of the illuminated area itself is not feasible with these types of illumination packages. As the fields of view decrease, the light packages will still provide adequate illumination, but experimental areas outside the smaller fields of view will also be illuminated.

G.9 3.2.2.1.3b PI experiment payload accommodation.

The FIR shall provide a minimum of 0.45 m^3 of space for payload equipment within its envelope with an additional 0.60 m^3 of optionally available for use by payloads if they do not require FIR provided diagnostics.

G.9.1 Exception to PI experiment payload accommodation.

The FIR System can only provide approximately 0.50 cubic meters if PI doesn't use any FIR provided diagnostics.

G.9.2 Rationale for exception to PI experiment payload accommodation.

Based on the current rotating optics bench design and volume constraints of the ARIS ISPR and other Common FCF equipment components, it is not possible to provide more than 0.50 cubic meters of volume for the PI experiment payload.

G.10 3.2.1.4.2b Provide acceleration measurements up to 300 Hz.

FIR shall accommodate an acceleration measurement device as close as practical to the test cell. It shall be capable of measurements in three simultaneous orthogonal directions at levels from 10^{-2} to 10^{-6} g/g_0 and frequencies from 0.01 to 300 Hz.

G.10.1 Exception to provide acceleration measurements up to 300 Hz.

The FIR System design is not able to provide measurements with frequencies above 200 Hz.

G.10.2 Rationale for exception to provide acceleration measurements up to 300 Hz.

This requirement traces back to SRED requirement F3.2. The FIR will utilize a SAMS Free Flyer (FF) head. The Free Flyer sensor head is able to measure frequencies up to 200 Hz which is sufficient to meet the requirements of all basis experiments.

G.11 3.2.1.10b Provide light sheets.

FIR shall provide collimated beams and light sheets having adjustable size and position.

G.11.1 Exception to provide light sheets.

The FIR will not provide light sheets.

G.11.2 Rationale for exception to provide light sheets.

This requirement traces back to SRED requirement F9. Light sheets will be provided by the PI due to the need to be located immediately adjacent to the test cell, and the typical degree of customization required.

G.12 3.2.1.37d Analog output channels.

At least 16 channels of at least **[12-bit]** analog output resolution shall be provided to experiments that require them.

G.12.1 Exception to analog output channels.

The FIR will supply at least 8 channels of at least **[12-bit]** analog output resolution shall be provided to experiments that require them.

G.12.2 Rationale for exception to analog output channels.

This requirement traces back to SRED requirement F29. Based on the evaluation of the basis experiment, 8 D/A channels were found to be sufficient to accommodate the needs of the experiments.

G.13 3.2.1.26, 3.2.1.28, 3.2.1.30, 3.2.1.32 –Identify and provide temperature, pressure, force, and voltage transducers specifications to PI.

a. FIR shall identify temperature, pressure, force, and voltage measurement instruments or techniques appropriate to the needs of the basis experiments and verify their performances.
b. The transducer specifications, test information, and samples shall be made available to PI hardware developers.

G.13.1 Exception to identify and provide temperature, pressure, force, and voltage transducers specifications to PI.

FIR will not identify temperature, pressure, force, and voltage measurement instruments or techniques appropriate to the needs of the basis experiments and verify their performances. FIR will not provide transducer specifications, test information, and samples to PI hardware developers.

G.13.2 Rationale for exception to identify and provide temperature, pressure, force, and voltage transducers specifications to PI.

The temperature, pressure, force and voltage measurement instrumentation requirements trace back to SRED F21.2, F22.2, F23.2, and F24.2 respectively. Because there is a broad range of measurement instrumentation available, it is not feasible for FIR to identify and provide to the PI transducers specifications, test information, and samples. There is a degree of customization required for each experiment and advances in measurement instrumentation technology will make any general specifications obsolete. However, FIR will be able to provide the PI with interface specifications to the appropriate circuitry. FIR will also be able to perform an analysis to ensure that most common transducer types can be accomodated to alleviate any possible bandwidth concerns.

G.14 3.2.1.40.1 Photon counter.

The FIR shall provide two photon counters with analog or digital output. Radiation shielding for life expectancy shall be provided. The photon counters modules shall have dark noise.

G.14.1 Exception to photon counter.

The design of FIR shall not preclude the use of photon counters with analog or digital output.

G.14.2 Rationale for exception to photon counter.

It is expected that photon counters will degrade over time due to radiation so it is not practical to have photon counters as part of FIR permanent hardware. In addition, an evaluation of the fluid physics basis experiments, indicated very few experiments required it. PI experiment payloads that require photon counters will need to provide their own devices. FIR will have the capability to support correlator cards provided by the PI.

G.15 3.2.1.40.2 Correlator

The FIR shall provide a signal processor as a dedicated high-speed hardware correlator. It shall perform auto- and cross-correlation on at least two digital or analog inputs. It shall operate in real-time at 100% efficiency. Minimum performance shall be:

1. 160 nm (?) minimum sample time
2. 256 (?) delays for each of two independent channels;
3. 8, 16, and 32-bit modes

G.15.1 Exception to correlator.

The design of FIR shall not preclude the use of high speed correlator cards etc.

G.15.2 Rationale for exception to correlator.

An evaluation of the fluid physics basis experiments indicated very few experiments required the use of correlators. FIR will have the capability to support correlator cards provided by the PI.

G.16 3.2.1.14.2 Provide IR camera.

The FCF shall provide one, remotely controllable IR camera. The IR camera wavelength range shall be 8 to 14 microns.

G.16.1 Exception to provide IR camera.

FIR shall not preclude the use of remotely controllable IR camera with a wavelength range of 8 to 14 microns.

G.16.2 Rationale to exception to provide IR camera.

An evaluation of the fluid physics basis experiments indicated very few basis experiments required the use of an IR camera. FIR will have the capability to support an IR camera provided by the PI.

G.17 3.2.1.39 Provide the digital output signals with electrical characteristics as stated.

a. FIR shall be capable of simultaneously outputting multiple channels of Transistor-to-Transistor Logic (TTL)-level output signals (nominally 0 to 5 volts) to PI hardware, as required to accommodate the basis experiments
b. At least **[16]** channels outputting 1-bit at 5 volts shall be provided to experiments that require them.

G.17.1 Exception to provide the digital output signals with electrical characteristics as stated.

FIR will provide digital out signals, but not at the specified signal levels stated in the requirement.

G.17.2 Rationale for exception to provide the digital output signals with electrical characteristics as stated.

FIR will provide the required quantity of digital output signals. However, due to good electrical design practices to eliminate ground connections between packages and enhance noise immunity, optically isolated signals will be provided instead of TTL level signals. Characteristics of the signals and interface requirements will be provided to the PI.

G.18 3.2.2.3.1 FIR environmental control system power allocation.

The FIR environmental control system power allocation shall not exceed, over a period of 30 minutes, 30 W or 8% of the input power to the FIR, whichever is greater.

G.18.1 Exception to the FIR environmental control system power allocation.

The FIR ECS may exceed 8% of the input power to the FIR.

G.18.2 Rationale for the exception to the FIR environmental control system power allocation.

FCF design of the ECS will minimize the power consumed by ECS. However, due to the capabilities that the ECS must provide, the FIR ECS may exceed 8% of the input power to the FIR.

G.19 3.2.4.5 Redundant paths.

The FIR, with applicable PI hardware, shall be designed to provide for alternate or redundant functional paths of all electrical and electronic harnesses that cannot be replaced on-orbit

G.19.1 Exception for redundant paths.

FIR will not provide redundant functional paths of all electrical and electronic harnesses that cannot be replaced on-orbit.

G.19.2 Rationale for the exception for redundant paths.

In order to provide redundant functional paths of all electrical and electronic harnesses that cannot be replaced on-orbit, great complexity in the design of elements containing and packages utilizing these harnesses would be incurred. The design will attempt to make harnessing accessible for replaceable under malfunction conditions and/or redundant. Some harnessing will not be able to comply with either of these requirements. Provisions during the buildup of the harnesses will allow for inspection of detailed workmanship. The reliability of the harnessing is good; an acknowledged minimal risk is accepted for these harnesses that cannot be replaced on-orbit.

G.20 3.3.1.1.3 Connectors.

Connectors used in the FIR, external to the assembly level, shall consist of MIL-C-38999, MIL-C-5015, MIL-C-81569, MIL-C-83733, or SSQ 21635 as specified in SSP 30423, Figure 4.1-8.

G.20.1 Exception to connectors.

FIR may utilize connectors other than those stated in the requirement when all connector options have been investigated and none meet packaging requirements.

G.20.2 Rationale for exception to connectors.

During the design of packages with external connectors, every attempt will be made to utilize connectors on the list. However, due to packaging constraints, no connector options may exist that will meet the application. Therefore, alternative connectors may be investigated, and evaluated against requirements imposed on them, including human factors, materials, flammability, etc., for determination if they can be used.

G.21 3.3.3.2.4 Connector coding and labeling.

Each FIR electrical connector pin shall be uniquely identifiable in each electrical plug and each electrical receptacle. At least every 10th pin must be labeled.

G.21.1 Exception to connector coding and labeling.

FIR shall not label at least every 10th pin.

G.21.2 Rationale for exception to connector coding and labeling.

Some of the connectors chosen for use in FIR may not be labeled at least every 10th pin, i.e. 25 pin DSUB. However, the pins will be labeled.

G.22 3.2.1.33 Acquire analog data.

FIR shall be capable of simultaneously sampling multiple channels of analog signals originating in PI hardware with sampling rates, as required to accommodate the basis experiments

G.22.1 Exception to acquiring analog data simultaneously.

The FIR shall not acquire analog data simultaneously.

G.22.2 Rationale for exception to acquiring analog data simultaneously.

In order to acquire analog data truly simultaneously, every analog input channel would require an A/D or sample-and-hold circuit. Due to the amount of circuitry this would require and the number of basis experiment requiring truly simultaneous sampling, truly simultaneous sampling will not be performed. However, multiplexing of channel inputs will be provided, allowing nearly true simultaneous sampling. This will provide the PI with the most benefit, and number of channels.

APPENDIX H TBD

H.1 Scope.

The scope of this appendix covers open issues and to be determined (TBD) items.

H.2 TBDs

TBD Number	Description	Document Paragraph
03-01	The "g-jitter Exclusion Envelope" figure from the SRED does not include all of the experiments as does the "Maximum Quasi-steady g-Level Limits" figure.	Figure 6
03-02	FCF System Specification requirement 3.2.5 does not identify the exact wording of availability requirement.	3.2.5
03-03	Initial scheduled experiment capacity.	3.2.1.1.3.2
03-04	EPCU Shutoff Switch Assembly	3.1.6
03-05	Atmospheric Monitoring Assembly	3.1.6
03-06	The FIR, with applicable PI hardware, when integrated into the FCF, shall not exceed a power draw of <TBD 03-06> W.	3.2.2.3b
03-07	Maintainability.	3.2.4
07-01	Verification Method for 3.2.1.1.3.2	APPENDIX F
07-02	Verification Method for 3.2.1.14.1a & b	APPENDIX F